WIRING SIMPLIFIED

by

H.P. Richter

22nd EDITION

PRICE 35c

"I WILL STUDY AND GET READY AND
SOME DAY MY CHANCE WILL COME"

Abraham Lincoln

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by

H. P. Richter

Member of
International Association of Electrical Inspectors
American Society of Agricultural Engineers

Copyright 1951
Park Publishing Co.

All wiring methods shown in this book are based on the latest (1951) National Electrical Code

22nd Edition

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PREFACE

This book has been written especially for those who want to learn how to install electrical wiring, so that it will be satisfactory to the owner of the building, and will also comply with electrical Codes. Then the finished job will be acceptable also to electrical inspectors, power companies, and others having jurisdiction in the matter. Electrical wiring cannot be learned by skimming through this or any other book for 15 minutes, but careful *study* of this book (plus investigation of such local ordinances as there may be, and observation of local customs), should enable you to wire a house or farm, so that it will be acceptable to everyone concerned. *However, before doing any wiring, learn how to do the job correctly, or hire an electrician who knows how.*

The author hopes this book will also be of considerable value to you in *planning* a wiring job (regardless of who is to do the work), to enable you to write sensible specifications which will lead to your securing the greatest usefulness from electricity. Careful planning will do away with later changes which usually cost twice as much as when included in the original plans.

Finally, I hope the book may be interesting to the man who is just naturally curious, and wants to know how things are done and why—the man who still has in himself something of the spirit of the boy who takes the clock apart just to see what makes the wheels go around.

Throughout this book I have emphasized the reasons *why* things are done in a particular way. This will help you to understand not only the exact problems discussed, but will also help you to solve other problems as they arise in actual wiring of all kinds.

Suggestions for the improvement of this book will be greatly appreciated by the author.

H. P. RICHTER

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CHAPTER 1

Underwriters and Codes

Electricity daily helps us in a thousand chores: it lights our homes, operates flat irons, toasters, washing-machines, and many other appliances; it runs motors of every description; it makes possible the telephone, the radio, the X-ray, even the automobile. All this is done without danger to the user, and accordingly electricity is taken for granted. Yet electricity can cause fires; it can kill people and destroy property. It does its work *safely* only because in our homes and in industry it is *under control.*

The thousands of different electrical parts and devices in use today are not made exactly the way hundreds of different manufacturers think they should be made; they are not installed in any fashion that workmen in different localities may wish to install them. They are built to entirely definite minimum safety standards, they are installed in a manner which is quite uniform throughout all states, and in a manner which experience has proved safe and practical.

Underwriters—All this did not just happen that way. Merchants with a reputation to protect will sell only merchandise which is "Approved by Underwriters"; this guarantees that the quality is up to the minimum set up by the Underwriters. The Underwriters are a set of laboratories supported jointly by manufacturers, insurance companies, and other interested parties. Manufacturers submit samples of their products to the Underwriters; the samples are tested and if they come up to the minimum quality required, the merchandise is then "Listed by Underwriters" or "Approved by Underwriters." Then the Underwriters regularly test samples secured

Fig. 1-1. Above are shown examples of labels applied on merchandise which is Approved by Underwriters.

from factories as well as bought in stores, and as long as the merchandise continues to come up to the minimum standards, it stays on the approved list.

Some things (like wire, large switches, fixtures, conduit) have an Underwriters' label similar to that shown in Fig. 1-1 on each coil or piece. Other devices (like receptacles, toggle switches, and similar items) carry the words "Und. Lab. Insp." molded or stamped on each piece. Still other pieces (like sockets, outlet boxes, electric irons, toasters, and similar items) do not carry labels but the nameplate, tag or carton bears the marker of Fig. 1-2, indicating approval. Not all approved merchandise is so marked, but each piece

must be marked in some way so that the electrical inspector in the field, as well as the purchaser, can identify the manufacturer by referring to the Underwriters' book which carries a list of all approved merchandise. Often the identification is an initial, a number, or other mark; sometimes it is the manufacturer's name.

On lamp cords, a "bracelet" label as shown in Fig. 1-3 is applied every

Fig. 1-2. On some approved merchandise, the item itself is not marked but the tag or carton bears one of the markers shown at the left. "UL" means "Underwriters' Laboratories."

5 feet on the cord. If used on an assembled extension cord or appliance cord, this marker merely indicates that the wire used is approved; the devices on the ends of the wire may still be unapproved and possibly unsafe. Such assemblies are approved only if the Underwriters' label, as shown in Fig. 1-4, is slipped over the cord.

An automobile tire intended for use on a passenger car may be entirely suitable and safe for that purpose, but would be totally unsuitable and unsafe if used on a truck weighing four times as much as the passenger car. So too, "Approved by Underwriters" guarantees that the merchandise ap-

Fig. 1-3. Lamp cords bear the "bracelet" label shown at right, every 5 feet.

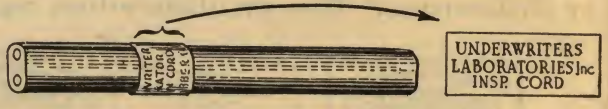


Fig. 1-4. Assemblies such as extension cords and appliance cords bear the "doughnut" label shown at right, slipped over the cord of which they are made. If they bear only the label of Fig. 1-3 it indicates only that the cord of which they are made is approved; the devices used on the ends of the cord may not be approved.

proved is suitable and safe *if used for the purpose for which it was intended.* It does not mean that the merchandise may be used regardless of circumstances; it may be used only for the purpose for which it was designed and only under the circumstances originally intended. It is on this basis that an electrical inspector will sometimes turn down approved merchandise; for example he will usually refuse to accept approved armored cable if used in a barn on a farm, because the Code does not permit its use in barns. The inspector will turn down approved lamp cord if used for permanent wiring,

because it is approved only for use on portable equipment. Fig. 1-5 shows the result of using it for a purpose for which it was not intended; a serious fire could easily have occurred.

Important: approval by Underwriters does not mean that two similar pieces of merchandise, both approved, are of the same quality. It merely indicates that both pieces meet the Underwriters' *minimum* requirements. One may just barely meet these requirements, the other far surpass them. For example, of two approved brands of toggle switches, one may average 5,000 "ons" and "offs" at full load before breaking down, the other 25,000. Use your own good judgment in making your choice of several approved brands, as you would in selecting other merchandise.

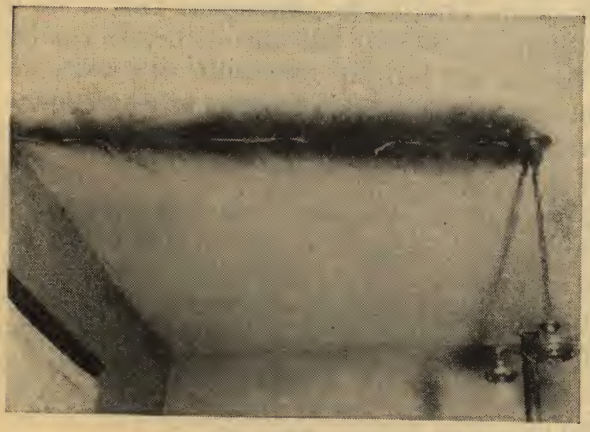


Fig. 1-5. Electrical materials should be used only for the purpose for which they were designed *and approved*. At the left is shown what may happen when approved material is misused. The lamp cord used may have been approved for use on floor lamps or radios, but certainly not for the use shown—a serious fire might have resulted.

Codes—Approved electrical parts of high quality, but carelessly or improperly installed, may still be dangerous, both as to shock and fire. For a safe installation, approved devices must be installed as required by the National Electrical Code. The Code* is simply a set of rules which outline the wiring methods that over a period of many years have been found to be safe and sensible. The Code permits many things to be done in several different ways, and all wiring must be done in one of the ways outlined in the Code.

The National Electrical Code is often supplemented by local Codes or ordinances which are never contrary to the National Code, but limit its application. For example, Armored-Cable wiring is one method permitted by the National Code, but sometimes prohibited by local Code.

All methods described in this book are in strict accordance with the latest (1951) National Electrical Code. This book covers only the wiring of houses and farm buildings; if here and there the statement appears that

* A copy of the National Electrical Code may be obtained by sending 15c to the National Board of Fire Underwriters, 85 John Street, New York, N. Y., or 222 W. Adams St., Chicago, Ill., or 1014 Merchants Exchange, San Francisco, Cal.

some particular thing is "always" required by Code, it means "always so far as the type of wiring described in this book is concerned."

Formerly, a new Code was issued every two or three years. Because of the war, there was a long lapse between the 1940 and the 1947 editions. The brand-new 1951 edition contains no changes of great importance concerning residential and farm wiring.

Study of the Code is necessary and will be helpful, but the Code alone will not teach you how to wire buildings. You will understand this statement better after you have read the following quotation from the Code: "The provisions of this Code constitute a minimum standard. Compliance therewith and proper maintenance will result in an installation reasonably free from hazard but not necessarily efficient or convenient. This Code is to be regarded neither as a design specification nor an instruction manual for untrained persons. Good service and satisfactory results will often require larger sizes of wire, more branch circuits, and better types of equipment than the minimum which is here specified."

Legal Aspects—Neither the Underwriters requirements nor the Code have the force of law. However, states and counties and cities pass laws which say that only Underwriters' Approved merchandise may be used in wiring, and that all wiring must be in accordance with the Code. R. E. A.* projects require the same. Usually power companies will not furnish power to buildings which have not been properly wired, and insurance companies may refuse to issue policies on buildings not properly wired. Therefore you have no choice except to follow the law, and in doing so you will automatically provide an installation which is thoroughly safe.

Permits—In many places it is necessary to get a permit from city, county or state authorities before a wiring job can be started. The fees charged for permits generally are used to pay the expenses of electrical inspectors, whose work leads to safe, properly installed jobs. Power companies usually will not furnish power until an inspection certificate has been turned in.

Licenses—Many cities and states have laws which require that no one may engage in the *business* of electrical wiring without being properly licensed. The author knows of no place, however, where an individual may not wire *his own* premises without a license; the permit, if required, must of course still be obtained. Before applying for the permit, be sure you understand completely all problems in connection with your job, so that your wiring will in every way meet Code and local requirements. If it does not, the inspector will be required to turn down your job until the mistakes are corrected.

* Rural Electrification Administration.

CHAPTER 2

Make a "Good Buy" in Your Electrical Installation

At some time or other you have probably bought something, a suit of clothes or a piece of furniture, a horse or an automobile, with which you were first greatly pleased; gradually you found out that you had not made a "good buy." Perhaps you did not know a great deal about the merchandise you were buying when you bought it, but believed what the seller said; as you learned more about that kind of merchandise, you gradually became dissatisfied with it.

Your electrical installation, even if first class materials are used and even if they are installed in entirely the right way, may still be a "poor buy." On the other hand, another installation about which you are not at first enthusiastic, may later turn out to be one of the "best buys" you have ever made.

If this seems confusing, consider some of the things involved. Especially if you are one of the fortunate farmers who are just receiving electrical service for the first time, you may at first be greatly pleased with an installation consisting of a bare bulb in each room (because it is such a wonderful improvement over a kerosene lamp); after a year or so, you will be highly dissatisfied. A "pull-chain" switch is much handier than using a match to light a lamp, but you will soon wish you had invested the extra few dollars which it costs to install a wall switch. *To add outlets to an installation later usually costs twice as much as when including them in the original job.* Therefore it is necessary to *plan* the installation carefully. Plan it so that you will be pleased with it not only when you first throw away your kerosene lamps and lanterns, but so that you will still be pleased and satisfied with it after a year or two. Look ahead to the equipment that you are going to be using next year, and the next. Do this, and you will have what is known in electrical language as "adequate wiring"—and you will automatically make a "good buy" in the installation.

An adequate electrical installation provides for the owner and his family many advantages, including

1. Convenience and comfort
2. Increased safety
3. Improved health and sight
4. Saving of time
5. Saving of money

Convenience and Comfort—Electricity makes light available anywhere, instantly, as much or as little as you wish. Radios provide comfort and relaxation, not to mention education for the children—all without the bother

of batteries. Electric clocks always show correct time and never need winding. Fans keep you cool in summer. Miles of walking and many hours of time are saved by running water which electricity makes possible. Electrically heated hot water is available at all times. Electricity makes it possible to have an oil burner, which does away with dusty coal and ashes, and lets you sleep an extra half-hour in the morning instead of getting up to start the fire. An electric range will not heat the kitchen like a coal or wood range, a decided comfort on hot days.

Increased Safety—Many thousands of fires are caused each year by kerosene lamps and lanterns and stoves. This danger is removed when electric power is used, but should there be a fire, an electric water-pressure system is a hundred times better than a bucket in putting it out. Many accidents are prevented by good electrical lighting. A yard light controlled from either house or barn prevents stumbling, discourages prowlers. Especially where there are children, an electric motor is safer than a gasoline engine; the motor starts instantly, without cranking.

Improved Health—Food can be kept safely for days in an electric refrigerator, months in a "deep-freeze." Scalding hot water always available from an electric heater means more sanitary surroundings, more destruction of germs. Running water made possible by electricity in turn makes possible sanitary systems like septic tanks and cesspools, doing away with unsanitary outhouses. In times of illness, an electric heating pad stays hot, does not cool off like the ordinary hot-water bottle.

9% of all children in grade schools, and 24% of those in high school, have defective eyesight; good lighting provided from infancy onward cuts this percentage in half. Many children today wear glasses, or should wear them, only because of poor lighting.

Saving of Time—In the house much time is saved by running water, by a refrigerator, by an electric range, as already discussed. Ironing is more quickly done with an electric iron, always at the proper temperature, with no need for keeping a fire going (perhaps on a hot day) to keep an old-fashioned iron hot. An electric washing machine does its work while the housewife is busy doing other things. A vacuum cleaner shortens the time required for cleaning. On the farm an electric motor runs for hours at a time, doing its work without attention. Many jobs can be done in less time with the help of a motor; other jobs that would otherwise require two men, can be done by one man and a motor. One survey shows that good lighting in the barn saves an average of an hour and a half per day.

Saving of Money—A refrigerator or "deep-freeze" prevents food spoilage. An electric range costs much less to operate than most people think, and uses power only while cooking; a wood or coal range uses fuel while coming up

to heat, and more fuel is wasted by burning up after the need for heat has passed. A man can deliver *continuously* not much over one-tenth horsepower; a motor delivering one-quarter horsepower costs at average rates only about 1½c per hour to run. A ½ hp. motor usually does everything a gasoline engine of 1 hp. will do and costs less; a 5 hp. motor does many of the jobs that tractors often are used for, and will still be running long after the tractor is worn out. An electric motor is not temperamental; it runs just as well on a blazing hot summer day as it does on a sub-zero winter day.

Paying Dividends—Artificial light provided for hens during winter, prolonging their work day, increases egg production during that part of the year when the price of eggs is the highest. Scalding hot water always available in a dairy will enable you to secure a higher price for milk; a milk-cooler leads to the same practical result. Many jobs can be done in less time and for less money with motors. Feed can be ground on the farm instead of hauling it to a custom grinder.

Install Enough Lighting—An adequately wired home is first of all well lighted. This does not mean expensive or elaborate lighting fixtures; $35 to $50 will buy attractive, scientifically correct fixtures for an entire house. It does mean outlets located so that fixtures will provide sufficient light at the points where it is needed. We'll talk about this in detail in a later part of this chapter.

Install Lots of Switches—An adequately wired home has wall switches so located that you can enter by front door or back, go from basement to attic, without ever being in darkness and still not leaving lights burning behind you. It does cost a few dollars more to install a wall switch, instead of using a pull-chain. Entirely aside from the added convenience, remember that wall switches can be considered accident insurance against stumbling over something while looking for a pull-chain in the dark. To install a pair of 3-way switches so that a light can be turned on or off from two different places (as for example upstairs or downstairs) costs only a few dollars more than the cost of a single switch, and is well worth the difference.

Install Lots of Receptacle Outlets—An adequately wired home has enough "plug-in" (receptacle) outlets of the type shown in Fig. 2-2 so that an extension cord is never needed for a lamp, a clock or similar device, even when the furniture is moved around. Extension cords are useful but their place is not in the living quarters of the house. Extension cords on the floor are dangerous because in stepping on them, they wear out, sometimes causing short circuits and fires. It is also easy to trip on them, causing accidents. In most places it costs less than three dollars to install a receptacle outlet. The National Electrical Code requires a *minimum* of one receptacle outlet for each 20 feet (or major fraction—10 feet or more) of circumference of a

room. Thus a room 14 by 18 ft. (which has a circumference of 14 + 14 + 18 + 18 or 64 ft.) requires not less than three. This is a minimum* and especially living rooms should have more.

Wire Size—An adequately wired home has wire of sufficient size. The Code says that No. 14 is the smallest size that may be used in ordinary wiring. Many wise home owners use No. 12 instead; it is not required but it means brighter lights, less power wasted in the form of heat in the wires. Doing this adds only a very small percentage to the total cost of wiring. In a few localities, No. 12 is required as a minimum.

Living Room—Suit yourself about whether to have a fixture in the center of the ceiling. Most homes no longer have them; the owners depend entirely on floor and table lamps for light. If you do depend entirely on lamps, have some of the receptacles into which they are plugged, controlled by wall switches as will be explained later.

Wall-bracket lights may be used if you like them. They are decorative but have little value for general lighting.

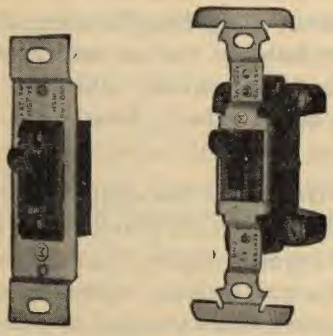


Fig. 2-1. Typical toggle switches. The one on the right has plaster ears which line the switch up flush with the plaster.

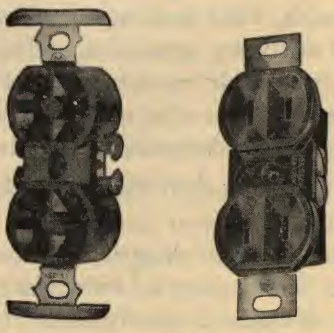


Fig. 2-2. Typical duplex receptacles. The one on the left is sturdier and will last longer than the one on the right.

There should be an absolute minimum of *four* receptacle outlets, one for radio, one for electric clock, two for floor lamps. Another should be located where convenient to reach, for vacuum cleaners and other appliances that are not left permanently plugged in. The best way is to follow the Code recommendation; then no point on the wall is more than 6 feet from an outlet.

Dining Room—One ceiling outlet for fixture should be provided; let it be controlled by a wall switch. Locate this fixture above the center of the table, rather than in the center of the room. Wall brackets may be provided if desired, but they are not very popular. There should be at least two "plug-in" receptacle outlets; be sure to locate them where it is easy to get

* The National Adequate Wiring Program in its "National Standards for Residential Wiring" recommends "convenience outlets so placed that no point along the floor line in any wall space unbroken by a doorway is more than 6 feet from an outlet in that space. At least one convenience outlet placed in every wall space 3 feet or more in length at the floor line.

at them. Too many dining room outlets are hidden behind furniture where it is almost impossible to reach them.

Kitchen—Provide a ceiling outlet for a fixture of the type shown in Fig. 2-3; control it by a wall switch, preferably by a pair of 3-way switches so that you can turn it on and off from either the back door or from the door into the dining room. Usually a bracket of the type shown in Fig. 2-4 is installed in addition, over the sink. *Fixtures that are installed where it is possible to touch the fixture and also a water faucet should be made of porcelain, not metal.* This is a safety measure for, should a defect in the fixture occur, a metal fixture makes a serious shock possible, but a porcelain fixture would prevent it.

Fig. 2-3. A typical kitchen fixture. It causes less eye-strain than an exposed bulb.

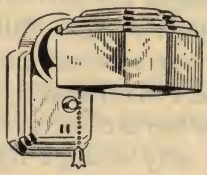


Fig. 2-4. The housewife appreciates a separate fixture above the kitchen sink.

Fig. 2-5. Fixtures with exposed bulbs should be used only in closets, basements, etc.

Install several "plug-in" receptacle outlets. Locate at least one of them about 10 inches above table level, for toaster, percolator, iron, etc. Another should be located where the refrigerator is to be placed. Even if you are not buying an electric range right away, it is wise to install a heavy-duty outlet for it at the time of the original installation. It will cost more later.

Bedrooms—Every bedroom deserves a ceiling light controlled by a wall switch. There should be two receptacle outlets, one on each side of the room. One should be easy to get at, for vacuum cleaner, and the other should be near the bed for a reading lamp, an electric heating pad, and so on. Do not overlook lights in the closets; simple pull-chain fixtures shown in Fig. 2-5 are suitable because most closets are so small that it is impossible to miss the chain. All the material required for a closet outlet will cost only a little over a dollar.

Miscellaneous—Locate a hall light so that it actually lights up the stairs —this reduces the danger of accident. 3-way switches should be used so that this light can be turned on and off from either upstairs or down. An outdoor porch light controlled by a switch inside the house is most handy. One of the basement lights should actually light the stairs, and should be controlled by a switch at the head of the stairs. By all means provide several receptacle outlets for use of washing machine, workshop, etc. Provide a light for the coal bin. The Code requires an outlet near permanently-installed laundry tubs. In all miscellaneous locations, be generous with lights;

a 50-watt bulb at average rates can be burned at least four hours for one penny. A light is usually installed in the garage, controlled from either house or garage.

Lighting Fixtures—The finest light in the world is natural sunlight. At night we use lighting fixtures to provide artificial light in place of it. Spend as much or as little money for them as you please, but make sure that the fixtures you select are good light-producers and not mere decorations, or fixtures that ruin eyesight. Many times one fixture will be much better from a lighting standpoint than another costing twice as much. Let us consider the question briefly: what is good lighting?

It is a well-known fact that on the average, 24% of high school students have defective eyesight; in colleges the percentage is over 30%. Poor lighting has surely caused a large part of this. The advertising slogan "Better Light, Better Sight" sums up the answer. Good lighting is today within reach of all, for good fixtures are inexpensive, bulbs are cheap, and in most localities a 100-watt bulb can be burned for over two hours for a penny.

Good lighting requires not only *enough light,* but also requires proper *distribution of light* throughout the room. Of course, a big bulb gives more light than a small one, but often a small bulb with a well designed fixture, will give better, more useful light than a larger bulb with a poorly designed fixture.

Fig. 2-6. Old-fashioned fixtures of this type, with exposed bulbs, should not be used. They do not provide good lighting and do produce eye-strain. They also produce much less light *per watt of electricity used* than modern fixtures with fewer but larger bulbs.

A fixture made so that you can see the bulbs from any part of the room, as for example that in Fig. 2-6, does not produce good lighting. True, such fixtures cost less, but the little extra cost for shaded-light ("semi-indirect") fixtures is one of the best investments you can make.

You have found that it is easier to read in the shade of a tree than in direct sunlight, even if there is less light in the shade. In the direct sunlight, the light all comes from one point, the sun; in the shade of a tree it comes from all around. Likewise, with fixtures that use exposed bulbs, the light all comes from one direction, causes sharp shadows and glare which make reading, sewing and other fine work impossible without eye-strain. Why? Let us consider how the eye operates. You know that the pupil of your eye changes in size; if there is much light, it becomes smaller, to reduce the amount of light entering the eye. If there is not much light, it

opens wide, to admit all the light it can. Watch your own eye in a mirror, with a dim light; see how big the pupil is. Then have someone turn on a bright light; see how small the pupil suddenly becomes.

Now, suppose you are reading under a bright light, from an exposed bulb. Out of the corner of your eye you can see the exposed bulb; it is very bright. The bright light entering your eye causes a message to go through the brain to the muscles controlling the eye: "Too much light—pupil smaller." At the same time, however, you look at the page of the book, and the light may be just right. The result is another message: "Light is right—pupil as is." Subconsciously you also see a corner of the room where the light is poor, and a third message comes along: "Not enough light—pupil bigger."

The result is that different muscles of the eyes fight each other over conflicting messages, and in turn there is straining, sore eyes, and sooner or later defective eyesight.

Consider now, light that is too dim; there is not enough light. The eye tries to adapt itself; the pupil tries to become bigger, when it is already as big as it can become. Result, more eyestrain.

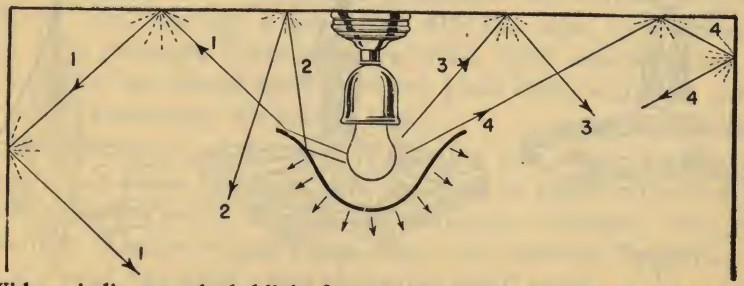


Fig. 2-7. With an indirect or shaded-light fixture, you cannot see the bulb. Light from the bulb is thrown to the ceiling and then reflected throughout the room. It is restful, glareless light.

Now, look at Fig. 2-7 which shows a "semi-direct" or "shaded" fixture. You cannot see the bulb. The shade itself is probably semi-transparent so that a certain amount of light filters through. Most of the light, however, hits the reflector, is thrown to the ceiling, then back into the room. A few individual rays have been numbered in the drawing—follow No. 1 from bulb, to reflector, to ceiling, to side wall, out to the room. Follow No. 2, No. 3 and No. 4. Actually, of course, the reflectors are so designed that light is distributed evenly throughout the room, and that is the secret of good lighting—a good supply of well distributed (diffused) light. There are no extremely bright spots, no extremely dark spots. The light seems to come from no particular place; it just simply is everywhere. Conflicting messages no longer go to the muscles of the eyes, but rather, they adjust themselves to the general level of the light in the room. That is why your eyes seem more rested after hours of work in a room with well diffused light,

than they do after working in a room with perhaps brighter light, but with glare and harsh shadows. The muscles of your legs become tired after continued use in walking; the muscles of your eyes also get tired from too much exercise. Give them a chance with good, well diffused light. Several types of typical "semi-indirect" or "shaded" fixtures appear in Fig. 2-8.

These paragraphs merely give you a basic idea of a few processes involved in seeing; actually it is a most complicated science on which entire volumes have been written. Today, correct lighting for homes is available from well-designed, practical and inexpensive fixtures that are at the same time attractive in appearance.

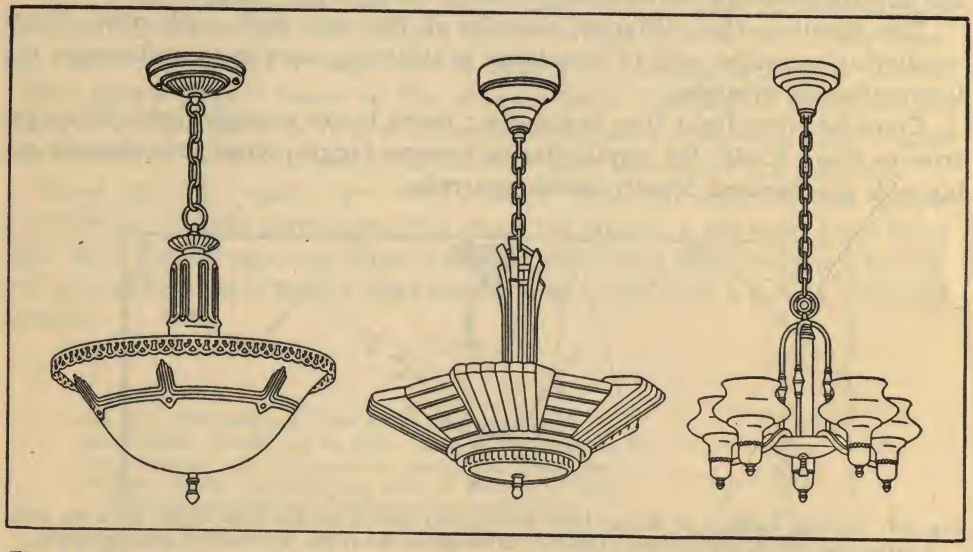


Fig. 2-8. Typical shaded-light fixtures, which provide restful, diffused light. Fixtures using a single bulb are the most efficient.

Do not be misled into thinking that shades on fixtures waste light and require much bigger bulbs; think in terms of eye-comfort rather than amount of light. Nevertheless, generally speaking it is true that the more light that is provided, the greater the comfort, if the light is diffused. In that connection remember that the larger bulbs are more efficient, give more light per watt of electricity used, than the smaller sizes. For example,

Three 60-watt bulbs (total 180 watts) give *10% more* light than five 40-watt bulbs (total 200 watts).

One 150-watt bulb gives *twice as much* light as five 25-watt bulbs (125 watts).

One 100-watt bulb gives *15% more* light than three 40-watt bulbs (120 watts).

From these figures it should be plain that a fixture that uses one large bulb, will in general provide much better lighting than one using several small

bulbs. The cost of operating bulbs is very low. At 5c per kw. hr., which is above the average, a 100-watt bulb may be operated two hours for one cent.

There is one important point to remember in connection with semi-indirect or shaded lights: your ceilings should be of a light color. A white ceiling will reflect most of the light thrown against it. Ivory is not quite as good. Next come buff and pink. Blue, grey, green, and brown are poor reflectors, and black reflects practically none. A flat finish is better than a glossy finish.

Considering these points, you will want to select semi-indirect or shaded fixtures; the style will depend on what you like and how much money you want to spend. Always, however, make sure the fixture you select is electrically good and safe: look for the Underwriters' label in the canopy of the fixture.

Fluorescent Lighting—This new type of lighting, first introduced not much over 10 years ago, is growing in popularity at an amazing rate, for it is a very great improvement over other forms of lighting. The bulbs are tubular, from 18 to 60 inches in length, consuming from 15 to 60 watts each. The electricity does not flow through a filament, but instead jumps from a contact at one end, through a gas which fills the tube, to a contact at the other end. This produces *invisible* ultra-violet light which strikes a chemical substance on the inside surface of the glass bulb, which in turn glows or "fluoresces" producing the visible light.

The chief advantage of fluorescent lighting lies in the fact that it produces from 2 to 4 times as much light *per watt of electricity used,* as compared with ordinary bulbs. Besides the saving in operating cost, this also greatly reduces the heat released in a room; this becomes important if large wattages are used, especially in a relatively small room.

Fluorescent bulbs can be used only in fixtures specially designed for them; there is no way of adapting them to fixtures designed for ordinary bulbs.

When buying fluorescent fixtures, buy only those which have "high power factor" and only those which use two or four bulbs each. Single bulbs produce a flicker which may be hardly noticeable on direct inspection, but which becomes most annoying and tiring especially in connection with fine work or reading.

Locating Fixtures in the Room—Hard and fast rules are hard to give, for so much depends on your own preference. Neither do all decorators agree on the subject.

Ceiling fixtures are usually located in the approximate center of the room. If there is a fireplace or mantel at one end, move the fixture a little toward the other end. If there is an open stairway at one end, move the fixture toward the other end.

In dining rooms, instead of locating the fixture in the center of the room, locate it so that it will hang over the center of the table. In kitchens, the center of the room is usually desirable, especially if you locate another bracket fixture over the sink.

Fixtures that hang from the ceiling (as compared with wall brackets) fall into three types:

1. **Drops**, usually with sufficient chain so that the bottom of the fixture will be from 36 to 42 inches below the ceiling.
2. **Semi-ceilings**, without chain but so constructed that the bottom of the fixture will be from 10 to 15 inches below the ceiling.
3. **Flush ceilings**, pieces that mount directly on the ceiling and project only a few inches.

Which type should you use in any particular case? A great deal depends on the ceiling height, the particular room that the fixture is used in, and the size of the room.

In general, large fixtures look best in large rooms. In dining rooms, the drop styles are generally used because there is no danger of bumping into the fixture, because the table is in the way. A fixture may hang 36 to 42 inches below the ceiling, but you can easily remove as many links as you wish from the chain supporting the fixture, shortening it considerably. Usually the bottom of the fixture is about 30 to 36 inches above the table level.

For living rooms, since you usually must walk under the fixture, a semi-ceiling type is usually used. If your ceiling is high, a drop type with supporting chain shortened, often looks better.

In bedrooms, use semi-ceilings or drops, as you prefer.

Flush ceiling pieces must necessarily have exposed bulbs, so should be avoided where possible. The only thing in their favor is low price, but since today good shaded fixtures for bedrooms and similar use are available at very reasonable prices, there really is no good excuse for not using them.

Floor and Table Lamps—As in lighting fixtures, make sure your lamps are efficient and produce good illumination. In general, lamps with a single bulb produce more light per watt used than any other type. The reflector style lamp with a special bulb with two filaments gives you a choice of 100, 200 or 300 watts (with a smaller bulb 50, 100 or 150 watts). Part of the light in such lamps is thrown upward against the ceiling, then reflected throughout the room, part of it comes downward through the glass or molded reflector to provide light below the lamp.

CHAPTER 3

Measurement of Electricity

Water is measured in gallons, wheat in bushels, meat in pounds. Electricity cannot be poured into a measure or weighed on scales, but rather is something which must be considered as always in motion, and our problem is to measure how much flows at any point, at any given moment, or in total over a period of time.

Amperes—The flow of electricity is measured in amperes, which corresponds to "gallons per minute" in a comparison with water. Note that the term is not amperes *per minute,* or amperes *per hour,* but just plain amperes.*

Volts—Water and air and other substances can be put under pressure; it is common to speak of such pressure in terms of pounds per square inch. Electricity is always under pressure, and that pressure is measured in volts. Any dry cell or flashlight cell, when new, develops a pressure of 1½ volts; one cell of your automobile battery develops 2 volts, the three cells together 6 volts. Most house wiring and farm wiring is at 115† and 230 volts. The voltage at which power is transmitted over high-voltage lines varies from 2,300 volts for short distances, to over 100,000 volts for long distances.

Watts and Kilowatts—Amperes alone or volts alone do not tell us the actual amount of power flowing in a wire, any more than "gallons per minute" tell us much about the work involved in pumping water unless we also know the pressure, or the depth of the well from which it is being pumped, which is almost the same as pressure. Both the amperes and the volts must be considered. The two together tell us how much power is flowing for *Volts* × *Amperes* = *Watts.*‡

Watts measure power just like horsepower does; as a matter of fact, 746 watts is always equal to 1 hp. A motor that delivers 1 hp. delivers 746 watts, and could just as well be called a 746-watt motor (it *uses* more than 746 watts because some power is wasted as heat and it also takes some power to run the motor even when it is not delivering power). A light bulb that uses 746 watts could just as well be called a 1 hp. bulb.

A watt is a very small amount of power; when speaking of large amounts of power, it is simpler to speak of kilowatts (the Greek word *kilo-* means *thousand*). One kilowatt (abbreviated kw.) is 1,000 watts.

* The absolute measure of quantity of electricity is the "coulomb." When electricity flows at such a rate that 1 coulomb flows in 1 second, we say that 1 ampere flows. Instead of saying that the current is "10 coulombs per second," we say that the current is 10 amperes. However, you can safely forget the word coulomb, because you will probably never meet it again unless you study electrical engineering.

† In most localities today the current in homes is 115- and 230-volt. In other localities it is 120- and 240-volt. In only a very few places is the formerly common 110- and 220-volt current still used.

‡ This formula is always correct with Direct Current, but with Alternating Current it is correct only part of the time. It is correct with lamp bulbs, flatirons and similar things; in commonly used devices it is wrong only with motors, where the watts are a good deal *less* than volts × amperes.

Again note that we speak of just watts, not watts *per hour* or kilowatts *per hour,* any more than you would say that the engine in your automobile delivers 90 hp. *per hour.*

Since *watts* = *volts* × *amperes,* any wattage may consist of either a low voltage and a high amperage, or a higher voltage and a lower amperage. A bulb which draws 10 amperes from a 6-volt battery uses 10 × 6 or 60 watts; another bulb which draws ½ ampere from a 120-volt line uses ½ × 120 or 60 watts. The voltage and amperage differ widely, but the actual power in the two bulbs is the same.

Watt-Hours and Kilowatt-Hours—One watt used for 1 hour is 1 watt-hour. Multiplying the watts used by the number of hours gives you watt-hours. A 50-watt bulb used for 6 hours consumes 50 × 6 or 300 watt-hours. A 600-watt flatiron used for 2 hours consumes 600 × 2 or 1,200 watt-hours. A motor using 1,000 watts, in 3 hours uses 1,000 × 3 or 3,000 watt-hours.

A watt-hour is a very small amount of power so it is more common to speak of kilowatt-hours; a kilowatt-hour is 1,000 watt-hours. The motor mentioned in the previous paragraph, consuming 3,000 watt-hours in 3 hours, consumes 3 kilowatt-hours, abbreviated kw-hr. Power is measured and paid for by the kilowatt-hour.

Fig. 3-1. The most modern type of kilowatt-hour meter has dials like the speedometer of an automobile, and is read in the same way.

One kilowatt-hour will operate the average flatiron for an hour, a washing machine for three hours. It will operate a 1 hp. motor for about an hour, or pump about 1,000 gallons of water. It will operate the average radio about 15 hours, a 50-watt bulb 20 hours. It will operate an electric clock for almost a whole month. One kilowatt-hour will do all this, and at average rates, cost less than five cents.

Reading Your Meter—Many meters being installed at the present time show the total kilowatt-hours on a register just like the speedometer of an automobile; see Fig. 3-1. The total is easily read.

Reading an old-style meter is a little harder, but you can learn how in a few minutes. Fig. 3-2 shows the register or dials of the meter. Two of the pointers move in one direction, the others in the opposite direction. Assume it is your meter at the beginning of the month. Simply write down, from left to right, the numbers that the pointers *have passed.* The total of the meter in Fig. 3-2 is 1,642 kw-hr.

The next picture, Fig. 3-3, shows the same meter a month later. One of the pointers points directly to the 7. Before writing down 7, look at the pointer on the dial to the right; it has not quite reached the "0." Therefore the pointer which seems to point directly to 7 has not actually reached the 7, so write down a 6 instead, making the total reading 1,969 kw-hr. (If the last pointer were just past the "0," the total would be 1,970.) The difference between the two readings, or 327, represents the number of kilowatt-hours used during the month.

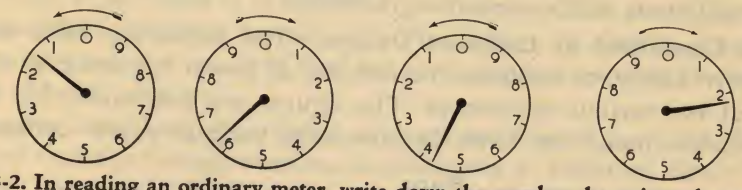


Fig. 3-2. In reading an ordinary meter, write down the number the pointer has passed.

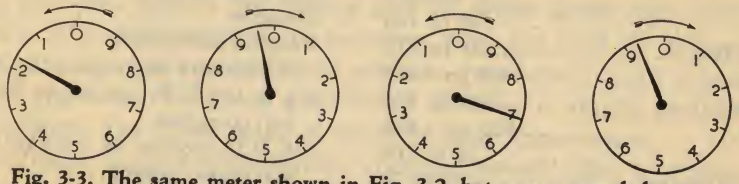


Fig. 3-3. The same meter shown in Fig. 3-2, but now a month later.

Power Rates—The rate charged for electricity averages considerably under 5c per kilowatt-hour throughout the United States, but varies greatly in different parts of the country. For home and farm use it is seldom as high as 10c and sometimes as low as 1c. Almost always there is a step rate so that the more electricity you use per month, the lower the average cost per kw-hr. A typical rate structure is as follows:

First 60 kw-hr. used per month.....6c per kw-hr.
Next 40 kw-hr. used per month.....3c per kw-hr.
All over 100 kw-hr. used per month.....2c per kw-hr.

Your bill for the 327 kw-hr. used in the example of the previous paragraph is figured this way:

60 kw-hr. at 6c	$3.60
40 kw-hr. at 3c	1.20
227 kw-hr. at 2c	4.54
327 kw-hr. Total	$9.34
Average per kw-hr., approximately	$ .028

Operating Cost Per Hour—To find out how much it costs to operate any electrical device for one hour, simply multiply the watts the device consumes, by the rate in cents per kw-hr. and point off five places; this gives

the cost in dollars per hour. For a 60-watt bulb at 5c per kw-hr., the figures are: 60 × 5 = 300; pointing off five places makes 0.003 or 3/10 cent per hour. For a 600-watt flatiron at 6c per kw-hr., the figures are: 600 × 6 = 3,600; pointing off five decimals makes 0.036, a little over 3½ cents per hour.

To determine how long any device may be used to consume one kw-hr., simply divide 1,000 by the wattage of the device. For example, a 40-watt bulb may be used $\frac{1,000}{40}$ or 25 hours. A 600-watt flatiron may be used $\frac{1,000}{600}$ or 1.666 hours or 1 hour 40 minutes. An electric clock uses about 2 watts and will run 500 hours while consuming 1 kw-hr.

Watts Consumed by Common Devices—The following table should at times prove handy, to estimate the amount of power required, or the operating cost for various appliances. The figures are not exact, for different manufacturers make the same devices with various power consumptions.

	Watts		Watts
Bulbs	7½ upward	Hot plates, per burner	500 to 1,000
Radio	40 to 100	Mangles	1,200 to 1,500
Refrigerator	200 to 275	Ranges, per burner	500 to 1,200
Flatiron	660 to 1,000	all burners and oven	up to 12,000
Percolator	500 to 660	1/6 & 1/5 H.P. motors as on refrigerators	275
Toaster	660 to 1,000	1/4 H.P. motors as on washing machines, pumps	325
Fans	25 to 100	1/3 H.P. motors	375
Sewing Machine	50 to 75	1/2 H.P. motors	600
Heating Pad	10 to 35	3/4 H.P. motors	775
Sunlamps	350 to 600	1 H.P. motors	1,000
Clocks	1 to 3	5 H.P. motors	4,500
Vacuum Cleaner	150 to 350	Water Heaters (tank type)	1,500 to 3,000
Kitchen Mixers	150 to 250		
Portable heaters	600 to 1,500		
Christmas tree lights, per string	30 to 50		

D.C. and A.C.—On a battery, one terminal is *always* + (positive), the other is *always* — (negative). Any current where each wire is always of the same "polarity," either positive or negative, is known as direct current or D.C. Current from a battery is always Direct Current.

The current used in practically all city homes, and in every "high line" in the county, is known as Alternating Current or A.C. because each wire changes or alternates continually from positive to negative to positive to negative and so on. The change from positive to negative and back again to positive is known as a "cycle." Usually this takes place 60 times every second, and such current is then known as 60-cycle current. 60 times every second each wire is positive, and 60 times every second it is negative, and 120 times every second there is no current at all in the wire. The voltage is never constant but is always gradually changing from zero to a maximum of usually about 162½ volts, but averaging 115 volts, and such current is then known as 115-volt current. You may ask the question, if there is no

current in the wire 120 times every second, why do not lights flicker? They do not flicker because the filament in the bulb does not cool off fast enough. Very small bulbs used on 25-cycle current (where there is no current in the wire 50 times every second) do have an annoying flicker.

Single- and 3-Phase Current—The current described in the previous paragraph is single-phase current. Remember that if 115-volt 60-cycle current flows in a pair of wires, 120 times every second the wires are dead, there being no voltage at all; 120 times every second, the voltage is about 162½ volts; at all other times it is somewhere in between, but averaging 115 volts. It is therefore anything but steady; the voltage is always changing. The changes however are so rapid that for most purposes it can be considered a steady 115-volt current.

Imagine now three separate electric generators all on a single shaft, so arranged that the voltage reaches its maximum at different times in each of the three generators: first in one, then in the second, then in the third, then again in the first, and so on. Run a pair of wires from each of the three generators. The three generators together then are said to deliver 3-phase current (although the current from any one generator is still single-phase). In actual practice, the three generators become a single generator with three windings; the three pairs of wires become three wires.

A 3-cylinder engine will deliver steadier power than a single-cylinder engine; so also 3-phase current will deliver steadier power than single-phase current (provided the device that consumes the current is one designed to operate in fact with 3-phase power). The most ordinary use of 3-phase power is in operating electric motors; single-phase motors are seldom practical in sizes larger than 5 hp. A 3-phase motor of any given horsepower is considerably smaller and simpler in construction than the same horsepower in the single-phase type, and costs less.

Three-phase power is common in cities especially in factories and similar establishments where there are many motors. It is seldom found on farms for to provide it, much costlier transmission lines are required, as also much more expensive transformers at each farm. Do not be misled into thinking that because there are three wires in the service entrance, the result must be 3-phase current. Almost always 3 wires means 3-wire single-phase current. (3-phase current may have either 3 or 4 wires.) If however you are fortunate enough to have 3-phase current available, by all means use 3-phase motors.

CHAPTER 4

Wire Sizes and Types; Fuses

Electricity flows over wires. It flows much more easily over some materials than others; copper is the best material for ordinary purposes. If iron wire were used, it would have to be about 10 times as big as copper wire.

Copper wire sizes are indicated by number. No. 14 is the most ordinary; it is not quite as big as the lead in an ordinary pencil. Nos. 12, 10, 8, and so on are larger than No. 14; Nos. 16, 18, 20 and so on are progressively smaller. No. 14 is the smallest size permitted for ordinary house wiring, and No. 2 is the heaviest usually used in residential and farm wiring. Still heavier sizes are Nos. 1, 0, 00, 000, and 0000, the No. 0000 being almost half an inch in diameter. See Fig. 4-1. No. 16 and No. 18 are used mostly in flexible cords and the still finer sizes are used mostly in the manufacture of electrical appliances such as motors.

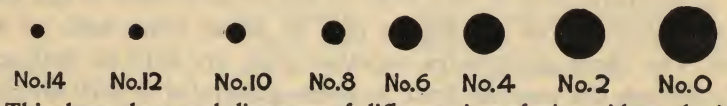


Fig. 4-1. This shows the actual diameters of different sizes of wire, without the insulation.

Why Wire Size Is Important—Wire of the correct size must be used, this being necessary for two reasons: carrying capacity and voltage drop.

When current flows through wire, it creates a certain amount of heat. The greater the amperage flowing, the greater the heat. (Doubling the amperes without changing the wire size increases the amount of heat *four* times.) This heat is entirely wasted; therefore to avoid wasted power, we must use a wire size which limits the waste to a reasonable figure. Moreover, if the amperage is allowed to become too great, the wire may become so hot that it will damage the insulation or even to cause a fire. The Code is not particularly concerned with wasted power, but is chiefly concerned with safety; therefore it sets the maximum amperage that various sizes and types of wires are allowed to carry, the amperages being as follows:

Wire Size	Rubber-covered Wire		Weather-proof wire
	In cable, or conduit	Knob-and-tube work	
14	15 amps.	20 amps.	30 amps.
12	20	25	40
10	30	40	55
8	40	55	70
6	55	80	100
4	70	105	130
2	95	140	175
0	125	195	235

Note:. The Code differentiates between wires in cable or conduit, and open wires which dissipate heat more readily and accordingly may carry more amperes.

The Code also recognizes several additional types of rubber-covered wire which have greater capacities than shown at left, but since these are specialized types little used in house wiring, they will not be shown here.

If forcing too many amperes through a wire caused only a certain amount of wasted power, we might look upon it as a mere nuisance and loss. However, it also causes *voltage drop*. Actual voltage is lost in the wire so that the voltage across two wires is lower at the end than at the starting point. For example, if you connect two voltmeters into a circuit, as in Fig. 4-2, one at the main switch, one across a 1 hp. motor at a distance, you will find that the voltage at the motor is lower than at the main switch. The meter across the main switch will usually read 115 volts. If No. 14 wire is used to the motor, the voltage across the motor terminals will be about 114½ volts with 10 feet of wire, but only about 103½ volts in the case of 200 feet of wire. The difference is lost in the wire and is known as voltage drop. Voltage drop is wasted power, but there is one other very important consideration:

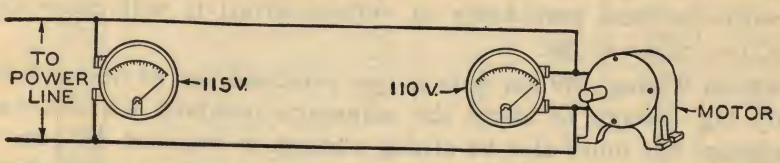


Fig. 4-2. This illustrates "voltage drop." The voltage at the motor is lower than the voltage at the starting point.

appliances work very inefficiently on voltages lower than the voltage for which they were designed. 103½ volts is 90% of the full voltage of 115 volts. At 90% of rated voltage, a motor produces only 81% of normal power; a light bulb produces only 70% of its normal light.

Selecting Right Size Wire—The Code requires that nothing smaller than No. 14 be used for ordinary wiring. It is better to consider No. 12 the smallest, this being required in some places by local ordinance. If wire heavier than the minimum permitted is needed, it is a fairly complicated matter to *figure* the right size, but a simple matter to look it up in tables prepared for the purpose.

First determine the amperage to be carried by the wire. To help you in arriving at the correct figure when motors are involved, use the following table:

Motor	115 v.	230 v.	Motor	115 v.	230 v.
¼ hp.	5 amp.	2½ amp.	1½ hp.	15 amp.	7½ amp.
⅓ hp.	6 amp.	3 amp.	2 hp.	20 amp.	10 amp.
½ hp.	7 amp.	3½ amp.	3 hp.	28 amp.	14 amp.
¾ hp.	10 amp.	5 amp.	5 hp.	46 amp.	23 amp.
1 hp.	12 amp.	6 amp.			

On page 27 appear two tables, one for 115 volts, the other for 230 volts; use the one that corresponds to the voltage of the circuit in question. All

distances shown are *one-way* distances; to operate a device 300 feet away requires 600 feet of wire, but look for the figure 300 in the table. The distances under each wire size are the distances that size wire will carry the different amperages (or wattages) in the left-hand column, with the customary 2½% voltage drop. For example, in the 115-volt table, to determine how far No. 8 wire will carry 20 amperes, follow the 20-ampere line until you come to the No. 8 column, and there is the answer: 110 feet. If 5% drop is to be allowed, double the distances shown. Where distances appear in *italics,* it indicates that only weatherproof wire may be used, for the amperages involved are greater than the carrying capacity of rubber-covered wire.

Compare the 115-volt and 230-volt tables; you will see that any given size wire will carry the same amperage *twice* as far on 230 volts as on 115 volts, with the same percentage of voltage drop; it will carry the same wattage *four* times as far.

Overhead Wiring—When wire is run overhead out of doors, it must be not only big enough to carry the amperage involved without excessive voltage drop, but must also be strong enough to support its own weight. Often it is called upon to carry also a heavy ice load. This frequently makes it necessary to use a wire larger than is electrically required. Requirements vary in localities, but REA specifications usually call for a minimum of No. 10 and that to be used only for spans not over 50 feet, and No. 8 or heavier for spans over 50 feet long. If distances are greater than 150 feet usually an extra pole is used, thus breaking the distance into two shorter spans.

The Code requires a minimum of No. 8 for the incoming power wires in any installation, unless the installation consists of a single circuit in which case a minimum of No. 12 may be used.

If the wire is installed on a hot summer's day, remember the wire will shrink a couple of inches per 100 feet during cold winter weather; leave considerable slack otherwise the shrinkage of the wires in winter may pull the insulators off your buildings.

Kinds of Insulation—Bare, uninsulated wire may be used for electrical purposes in only a few cases which will be explained later. In almost all cases, the wire must be insulated. The insulation used on wires in common use in residential and farm wiring is usually rubber (natural or synthetic), sometimes plastic, except on weatherproof wire.

Weatherproof Wire—Weatherproof wire is used only out of doors, between buildings, and may *never* be used for indoor wiring. The insulation consists of three braids of cotton, thoroughly saturated with weatherproofing and light-resisting compounds. Fig. 4-3 shows its construction. It is always black in color and the copper conductor is always solid, not stranded. in sizes even as heavy as No. 2.

TABLE OF WIRE SIZES FOR 115 VOLTS

Amperes	Watts at 115 v.	Wire Size							
		No. 14	No. 12	No. 10	No. 8	No. 6	No. 4	No. 2	No. 0
1	115	550	875	1,400	2,200	3,500	5,500	8,800	14,000
2	230	275	440	700	1,100	1,750	2,750	4,400	7,000
3	345	185	295	465	735	1,250	1,850	2,950	4,650
4	460	140	220	350	550	875	1,400	2,200	3,500
5	575	110	180	280	440	700	1,100	1,800	2,800
7½	862	70	120	180	300	475	750	1,200	1,800
10	1,150	55	90	140	220	350	550	900	1,400
12½	1,437	45	70	110	180	280	440	720	1,100
15	1,725	35	60	90	150	235	370	600	900
20	2,300	*27*	45	70	110	175	275	450	700
25	2,875		*35*	55	90	140	220	360	550
30	3,450		*30*	45	75	115	180	300	450
35	4,025			*40*	65	100	160	260	400
40	4,600				55	85	140	225	350
50	5,750				*45*	70	110	180	275
60	6,900					*55*	90	150	225
75	8,625						*70*	120	185
90	10,350						*60*	100	150
100	11,500							*90*	140

TABLE OF WIRE SIZES FOR 230 VOLTS (OR 3-WIRE 115/230 VOLTS)

Amperes	Watts at 230 v.	Wire Size							
		No. 14	No. 12	No. 10	No. 8	No. 6	No. 4	No. 2	No. 0
1	230	1,100	1,750	2,800	4,400	7,000			
2	460	550	875	1,400	2,200	3,500	5,500	8,800	14,000
3	690	370	590	925	1,475	2,500	3,700	5,900	9,300
4	920	275	440	700	1,100	1,750	2,750	4,400	7,000
5	1,150	220	360	560	880	1,400	2,200	3,600	5,600
7½	1,725	140	240	360	600	950	1,500	2,400	3,600
10	2,300	110	180	280	440	700	1,100	1,800	2,800
12½	2,875	90	140	220	360	560	875	1,450	2,200
15	3,450	70	120	180	300	475	750	1,200	1,800
20	4,600	*55*	90	140	220	350	550	900	1,400
25	5,750		*70*	110	180	280	440	720	1,100
30	6,900		*60*	90	150	235	370	600	900
35	8,050			*80*	130	200	320	525	800
40	9,200				110	175	275	450	700
50	11,500				*90*	140	220	360	550
60	13,800					*115*	180	300	450
75	17,250						*140*	240	375
90	20,700						*120*	200	300
100	23,000							*182*	275

In both tables above, figures represent ONE WAY distances, not the total length of wire back and forth. Distances shown in *italics* indicate that for the amperages in the same line in column at left, only weatherproof wire may be used. For all other distances either rubber-covered wire or weatherproof wire may be used.

Each figure indicates the maximum distance each size wire shown will carry the different amperages in the left column, with 2½% voltage drop. If you wish to permit 5% voltage drop, double the distances shown.

For 32-volt table see page 126; for 6-volt table see page 127.

Rubber-covered Wire—While many kinds of wire use rubber for insulation, only one particular kind is commonly known as "rubber-covered wire," and that is the common wire used for indoor wiring. Its construction is shown in Fig. 4-4; it consists of a copper conductor, usually tinned to make the rubber insulation strip off easily and cleanly, and to make soldering easier. Next comes a layer of rubber the thickness of which depends on the size of the wire. Over all comes a cotton braid, saturated with a compound that is moisture-resistant and fire-retardant; if set on fire by a blow-torch, the flame will go out when the torch is removed. Finally comes a layer of wax to make the wire slick and clean. If the wire is to be some color other than black, a layer of paint comes under the wax. The purpose of color will be explained in a later chapter.

Fig. 4-3. Weatherproof wire may be used only outdoors. There is no rubber in its insulation.

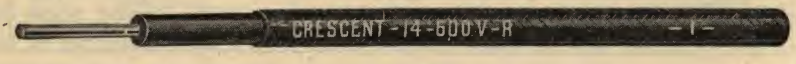


Fig. 4-4. Rubber-covered wire is used mostly indoors.

Rubber-covered wire in sizes No. 6 or heavier is usually stranded, that is, it has a copper conductor consisting of a number of small strands of copper wire twisted together; this makes the wire more flexible. A double cotton braid is also used for greater mechanical protection of the insulation.

Rubber-covered wire is usually used only indoors. It is not prohibited out of doors, but it is better to use weatherproof wire, which lasts longer, and in larger sizes costs less than the rubber-covered. Indoors rubber-covered wire may be used supported on insulators, or run through pipe known as conduit, or in the form of cables.

Cables—For a great many purposes, rubber-covered wires are bundled together into cables such as non-metallic sheathed cable or armored cable. These will be described in detail later. When a cable contains two No. 14 wires, it is known as 14-2 (fourteen-two) cable; if it has three No. 12, it is known as 12-3, and so on. If a cable contains two wires, one is always white, one black; if it contains three wires, one is white, one black, and the third is red.

Non-Metallic Sheathed Cable—This material, known by such trade names as Romex, Cresflex, Loomwire, etc., is shown in Fig. 4-5 and consists of two or more wires of the rubber-covered type, but usually without the final outer cotton cover. Instead, each wire has a paper braid, and over that a spiral wrapping of paper. The wires are then enclosed in an overall outer

braid of cotton, which is treated with moisture-resisting and fire-retardant compounds. The spaces that would otherwise be empty are filled with a jute or similar cord. A somewhat different construction designed especially for farm use is described in Chapter 15.

Non-metallic sheathed cable may not be used out of doors. It is the most common cable in use for farm wiring. It is relatively easy to install, is neat in appearance and less expensive than other styles of cable.

Fig. 4-5. Non-metallic sheathed cable consists of two or three rubber-covered wires assembled into a cable. It may be used only indoors.

Fig. 4-6. Armored cable consists of two or three rubber-covered wires assembled into cable, protected by flexible steel armor. It may be used only indoors.

Armored Cable—In this style of cable, which goes by such trade names as BX, Flexsteel, etc., pictured in Fig. 4-6, the wires are of the rubber-covered type including the outer cotton braid. They are then wrapped in paper and the final protection is a spiral wrapping of steel armor from which it gets its name. It may be used only indoors unless it is a type which has a lead sheath over the wires, in which case it may be used outdoors.

Underground Wires—See Chapter 12.

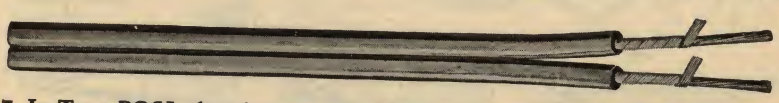


Fig. 4-7. In Type POSJ, the wires are imbedded in rubber. The cord is durable, attractive.

Lamp Cords—Flexible cords to connect appliances and other devices to outlets are known as lamp cords. Each wire consists of many strands of fine wire for flexibility. Over the copper is a wrapping of cotton to prevent the rubber insulation from sticking to the copper. The more common types will be described here.

Underwriters' Type POSJ is the most common cord used for radios, floor lamps and similar devices. As shown in Fig. 4-7, it consists of copper wires imbedded in solid rubber. It is tough, durable and available in an assortment of colors.

Underwriters' Type C is commonly known as "Green and Yellow." It consists as shown in Fig. 4-8 of two wires insulated with a heavy layer of

rubber, then with a serving of tough cotton, finally twisted. It is designed for rough use.

A really tough and knock-about cord is Underwriters' Type SJ shown in Fig. 4-9. Each wire is rubber-insulated; the two wires are then bundled into a round assembly, the empty spaces being filled with jute or paper twine to make it round. Over all comes a layer of tough, high-grade rubber. Type S is similar except that the outer layer of rubber is thicker, making a still sturdier cord.

Fig. 4-8. Type C cord is a good knock-about cord for rough use.

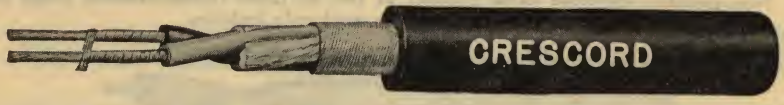


Fig. 4-9. Types S and SJ cord are designed for severest use.

Fig. 4-10. Type HPD cord is used on flat-irons, toasters, etc.

For flatirons and other devices delivering considerable heat, a special cord is required known as "heater cord." The most common type is Type HPD and Fig. 4-10 shows its construction. A layer of asbestos is applied over each wire before twisting. Over all comes a layer of rayon or cotton; the cotton is by far the more durable.

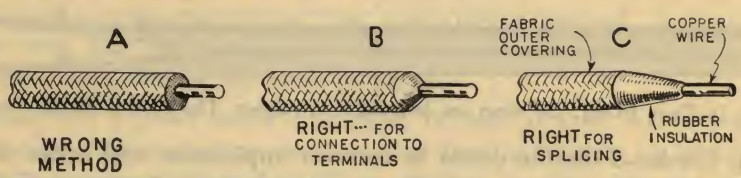


Fig. 4-11. Wrong and right methods of removing insulation from wire.

Removing Insulation—Before a wire can be attached to a switch or other device, or spliced to another wire, the insulation must be removed. There is a right and a wrong way. Do not cut it off sharply, as shown in *A* of Fig. 4-11; there is too much danger of nicking the copper wire, leading to breaks later. If the wire is to be attached to a terminal, hold your knife at an angle as shown in *B* of Fig. 4-11. If the wire is to be spliced to another wire, hold the knife as in sharpening a pencil and as shown in *C* in the same picture.

Whether the wire is to be attached to a terminal or is to be later soldered, you absolutely *must* remove all traces of insulation from the copper conductor. Some kinds of wire have a tinned copper conductor which makes it easy to strip the insulation off cleanly. Other kinds, such as weatherproof, require considerable scraping to clean the conductor. Always make sure the conductor is absolutely clean.

Terminals—Terminals to which wires are connected are of two types. If the wire is No. 8 or lighter, usually the common screw terminal shown in Fig. 4-12 is used. Bend the end of the wire into a loop, insert it under the head of a terminal screw so that, as the screw is tightened, it tends to tighten the loop. Fig. 4-13 shows the right and wrong ways. If the wire is No. 6 and heavier, only terminals or connectors similar to that shown in Fig. 4-14 are permitted. The end of the wire is not looped but is merely inserted into the connector; when the screw is driven down tightly, an entirely secure and electrically good joint is made. Regardless of the type terminal involved, *be sure the insulation on the wire comes up close to the terminal.*

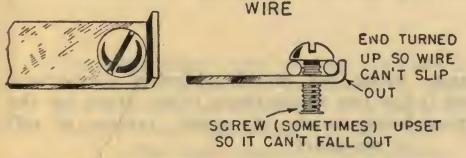


Fig. 4-12. Common terminal for small wires. The end is turned up to keep the wire in place.

Fig. 4-14. Solderless terminals of the type shown are used for heavy sizes of wire.

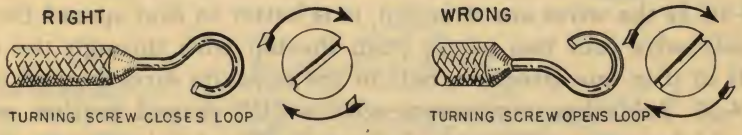


Fig. 4-13. Always insert the loop on a wire so that tightening the screw closes the loop.

Splices—Where splices are permitted, they must be properly made. This means that the spliced wire must be as strong mechanically as an unbroken piece of the original wire. Electrically, it must be as good a conductor as an unbroken piece, which requires proper soldering, or using approved solderless connectors. The splice must have as good insulation as a continuous piece of wire, which requires proper taping.

Where there is no mechanical strain on the joint, as for example where two wires are joined in an outlet box, a very simple splice is sufficient. Twist the two wires together, as shown in Fig. 4-15, solder, and tape. If preferred, approved solderless connectors of the type shown in Fig. 4-16 may be used. They have internal threads so that it is merely necessary to hold the stripped ends of the wires in one hand, screw the connectors on tightly

with the other. If one wire is much smaller than the others, let it project a bit further than the others. If no bare wire is allowed to stick out of the connector, the joint does not require taping.

For heavier wires, *if there is no strain on them,* a simple splice can be quickly and securely made using heavy-duty solderless connectors of the type shown in Fig. 4-17. Tape must still be applied over the connector.

If two wires are to be spliced and there *is* strain on the joint, the steps shown in Fig. 4-18 will show you how to proceed. The finished joint must be soldered and taped.

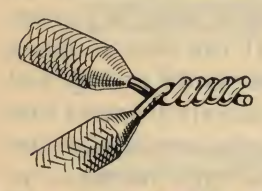


Fig. 4-15. If there is no strain on the wires, merely twist them to splice.

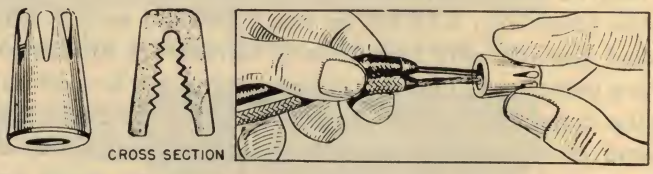


Fig. 4-16. Solderless connectors shown above are simply screwed on to the wires to be spliced. No taping is necessary.

Fig. 4-17. For heavier wires, use metal solderless connectors. The type shown here is for use where there is no strain on the wires. The connectors being made of metal, taping is still necessary.

If one wire is to be tapped to another continuous wire, handle as shown in Fig. 4-19. If the wires are stranded, it is better to first spread the strands in the main wire into two parts; push the tap wire through the opening, wrap half of it in one direction, half in the opposite direction, all as shown in Fig. 4-20. Solderless connectors with a "U" shaped section over both parts of which a nut is tightened, as shown in Fig. 4-21, are most convenient for this purpose and save a great deal of time.

Fig. 4-18. When there is strain on the wire, splice as shown at left and above.

Soldering—The first requirement of good soldering is that both the wire and the soldering-copper must be absolutely clean. Use a non-acid flux; rosin is suitable for the purpose and rosin-core solder in wire form is handy. In soldering, apply the hot soldering copper to the joint, until the wire itself

is hot enough to melt the solder when it is touched to the wire, as shown in Fig. 4-22. This will allow the solder to flow down into the little open spaces in the splice, making a good electrical joint. See Fig. 4-23 for the difference between poor and good soldering.

Fig. 4-19. Tapping one wire to another continuous wire is simple as the picture at the left shows.

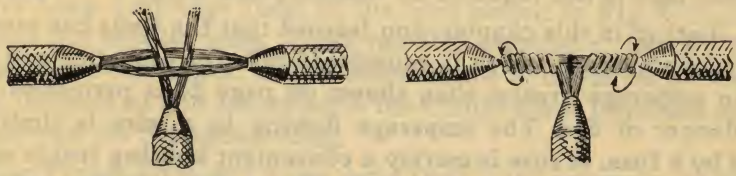


Fig. 4-20. If the wires are stranded, the construction shown above is better than that of Fig. 4-19.

Fig. 4-21. Heavy sizes of wire are hard to tap and solder properly, especially in awkward locations such as at the top of a pole. Heavy-duty solderless connectors of the type shown at the right simplify the problem.

Fig. 4-22. In soldering, heat the wire until it is hot enough to melt solder.

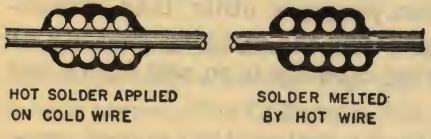


Fig. 4-23. When hot solder is applied on cold wire, it does little good because most of it lies on the surface of the wire. If the wire is heated so that it melts the solder, the solder will run down and fill all spaces.

Taping—Every soldered joint must be properly taped. Two kinds of tape are used. Rubber tape, also known as splicing compound, replaces the insulation; friction tape replaces the outer protective braid on the wire.

Rubber tape is a very high grade of unvulcanized rubber which, under slight pressure, vulcanizes to other rubber. Wrap a couple of layers of this rubber tape tightly around a pencil, one on top of the other, then cut through it. You will find one thick solid layer; the several thin layers have vulcanized together. In applying the tape on a splice, start it on the tapered end of the rubber insulation of the wire, wrap toward the other end, then back and forth until the layer of rubber is as thick as the original insulation. Keep the tape stretched tight at all times. Follow with a layer or two of friction tape. Rubber tape is not required on weatherproof wire.

Fuses—Earlier in this chapter, you learned that the Code has established the maximum amperage which is considered safe for each size and type of wire. If an amperage greater than shown on page 24 is permitted to flow, there is danger of fire. The amperage flowing in a wire is limited to a safe value by a fuse. A fuse is merely a convenient housing inside of which is a piece of metal, made of a material and in a size which experiment has shown will melt when more than the specified amperage flows through it. For example, a 15-ampere fuse carries 15 amperes continuously, but when more than 15 amperes flows through it, the fuse blows (the wire inside the fuse melts), which is the same as cutting the wire.

Fig. 4-24. Plug fuses are not made larger than 30 amp.

Fig. 4-25. Cartridge fuses of this type are made in all sizes up to 60 amp.

Fig. 4-26. Cartridge fuses 61 amp, and larger have knife-blade terminals shown above.

The branch circuits of a house may be protected only by 15-ampere fuses, even if No. 12 wire has been used to reduce voltage drop. However, the one appliance circuit described on page 37, wired with No. 12 wire, may be protected by 20-ampere fuses. Wires used for purposes other than branch-circuits may be protected by fuses not larger than the carrying capacity of the wires as shown on page 24. If the carrying capacity is an odd figure, use the next larger *standard* fuse.

When two different sizes of wire are joined together, for example when No. 8 is used for an overhead run for mechanical strength, and No. 14 which is used for inside wiring is joined to it, the fuse must be the correct size for the *smaller* of the two wires. Of course, a fuse of the correct size for the *larger* wire may be used at the starting point, provided an additional

fuse of correct amperage for the smaller wire is used at the point where the wire size is reduced.

Fuses are the safety valves of electrical installations. To use substitutes, or something which prevents the fuse from operating, or fuses which are too large for the size of wire involved, is either ignorance or stupidity; either may easily lead to a fire. Don't do it, any more than you would tie down the safety valve of a steam engine or drive an automobile without brakes.

Plug fuses of the type shown in Fig. 4-24 are made only in the 30-ampere and smaller sizes. Cartridge fuses of the type shown in Fig. 4-25 are made in 60-ampere and smaller sizes. Those rated 30 amperes or less are 2 inches long; those rated between 31 and 60 amperes are 3 inches long. The larger ones rated between 61 and 100 amperes have knife blade terminals as shown in Fig. 4-26 and are 5⅞ inches long.

Time-Lag Fuses—Ordinary fuses carry their rated amperage indefinitely, but blow very quickly if twice that amperage flows through them. Fuses, therefore, often blow when a motor is started, because a motor which draws, for example, only 6 amperes *while running,* may draw 30 amperes or even more for a few seconds *while starting.* On the other hand, wire which can safely carry 15 amperes continuously (and which might be damaged or even cause a fire if 30 amperes flowed continuously) will not be damaged in the least (or cause a fire) if 30 amperes flow for a fraction of a minute. For this reason, a new fuse has been developed, known as the "time-lag" type. It is commonly called a Fusetron. It blows just as quickly as an ordinary fuse on a small continuous overload, or on a short circuit, but *it will carry a big overload safely* for a fraction of a minute. This type of fuse is rapidly becoming popular, especially where motors are used. It prevents needless blowing of fuses and does away with many service calls. It looks like an ordinary fuse but is made differently inside.

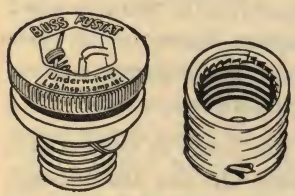


Fig. 4-27. A typical non-tamperable ("Type-S") fuse and adapter.

Non-Tamperable Fuses—Since all plug fuses are interchangeable, nothing prevents one from using for example a 25- or 30-amp. fuse to protect a No. 14 wire, which has a carrying capacity of only 15 amperes. That is unsafe. For that reason there has been developed a non-tamperable fuse, shown in Fig. 4-27; it consists of two parts: an adapter, and the fuse proper. The Code calls this a "Type-S" fuse; it is commonly called a Fustat. Once an adapter of any given size, say 15-amp., has been inserted in a fuse-holder, only fuses of that size or smaller can be used—a safety measure. The adapter once inserted into place, cannot be removed. The Code requires that on new installations, only this non-tamperable type of fuse may be used. This ruling does not affect installations already made.

Circuit Breakers—Instead of a fuse, a circuit-breaker may be used. When there is an overload, the circuit-breaker trips, which is just like opening a switch. A circuit breaker will not trip on a temporary overload which would blow an ordinary fuse. There is nothing to replace—merely reset it like turning on a switch. It entirely protects a wire but still carries a large but temporary overload long enough to permit a motor to start. One unit is shown in Fig. 4-28. Such breakers come in combinations up to six in a single cabinet, replacing an equal number of fuses.

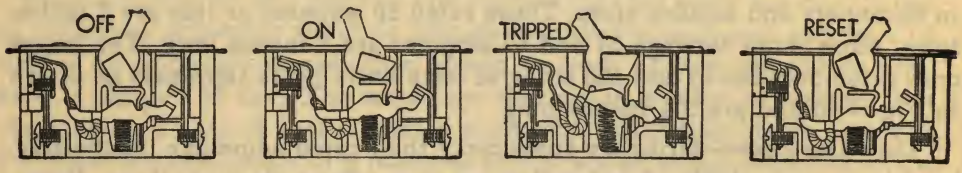


Fig. 4-28. Cross-section of a circuit breaker. It is used instead of a fuse. If it trips because of overload, reset as shown at right, then move handle back to "ON" position.

Branch Circuits—If all the lights and appliances in a home or on an entire farm were protected by a single fuse, the entire establishment would be in darkness when that fuse blows. That would be most inconvenient. Also, all the wires would have to be very large to match the amperage of that fuse, and that would mean a clumsy and expensive installation. Therefore, the different outlets* in an installation are separated into smaller groups known as branch circuits. Inexpensive No. 14 or No. 12 wire is used for most of the wiring, protected by 15- and 20-ampere fuses or circuit-breakers respectively. When one of these fuses blows, only those outlets on that circuit are dead; those on other circuits are still alive.

How Many Circuits to Use—First of all, so far as the Code is concerned, there may be as many outlets on one circuit as you wish. On the other hand, if you place too many on one circuit, you will not be able to use all of them at one time because then fuses will blow. In most cases you will want to have at the most a dozen outlets on one circuit, even if more are permitted.

The *minimum* number of circuits required for a house is easily determined. First figure the total number of square feet of area in the living quarters of the house, not including the garage or *unfinished* spaces in the basement or attic. For example, if a house is 30 by 32 feet and has two floors,

* Every point where electricity is actually used is an outlet. Each fixture, even if it has five bulbs, is considered one outlet. Each receptacle outlet, even if it is the duplex type, is one outlet. Switches are not outlets because they use no electricity, but merely control its use. Usually, however, in estimating the cost of an installation, switches are included in counting the outlets to arrive at a total cost on the "per outlet" basis, but this usage is not in accordance with the Code definition.

the total area is 30 × 32 × 2 or 1,920 square feet. If there is a finished* room 15 by 20 ft. in the basement, add its area of 300 square feet, making a total of 2,220 square feet.

The Code requires, *for the purpose of determining the number of circuits required,* that 3 watts per square foot be allowed for lighting purposes only, so for 2,220 square feet 6,660 watts must be allowed.

No. 14 wire has a carrying capacity of 15 amperes which, at 115 volts, is equivalent to 15 × 115 or 1,725 watts maximum capacity. Since 6,660 watts in total must be carried, the number of circuits is 6,660 divided by 1,725, or 3.8 circuits. There can't be a fraction of a circuit so 4 must be provided, for lighting only.

In addition, the Code requires that a special circuit must be provided to serve the receptacle outlets in kitchen, pantry, breakfast room, dining room, and laundry; it may *not* have any lighting fixtures connected to it, but only the receptacle outlets. This circuit *must* be wired with nothing smaller than No. 12 wire, and it may then be protected by 20-amp. fuses or circuit breakers. This circuit then has a capacity of 20 × 115 or 2,300 watts—sufficient to handle large roasters, flatirons, toasters, and similar appliances which would often blow the usual 15-amp. fuses, especially if several appliances are used at the same time.

The number of circuits determined as above outlined is the *minimum* required by the Code. In most cases, more than the minimum should be installed, to make an installation which is more adequate, more flexible, and involving less voltage drop and wasted power. Although the Code does not require it, it *recommends* one circuit for every 500 square feet of floor area plus one circuit for appliances. For the house with 2,220 square feet of area, five circuits would be required for lighting, and one for appliances.

If an electric range is to be used, it will require a special circuit of its own, and because part of it operates on 115 volts, part of it on 230 volts, three wires must be run to it.

A water heater which, in almost every case, operates on 230 volts, requires a special circuit. An oil burner, a stoker, or a water pump should have its own circuit. Any motor ½ hp. or larger should have its own circuit, as also any other device consuming over 1,650 watts.

* "finished" means suitable for living quarters, not for example a laundry room.

CHAPTER 5

ABC of Wiring

Before you can do actual wiring, you must study carefully the methods used in connecting switches, receptacles, sockets, and other devices with wires to make a complete electrical system.

Grounded Wire—In residential and farm wiring, one of the wires is always grounded, that is, connected to a water pipe or driven ground rod. It is most important that you remember the following 4 points:

1. The grounded wire is *always* white in color.
2. The grounded wire must run direct to every 115-volt device to be operated (*never* to a device operating only at 230 volts).
3. The grounded wire is *never* fused.
4. The grounded wire is *never* switched or interrupted in any other way.

With one exception, which will be covered later, white wire may never be used except as a grounded wire. All other wires are usually black but may be some other color, but not white, with the one exception just mentioned.

One black wire and one white wire are run to most electrical devices *other than switches.* Examine a socket or similar device carefully and you will find that one terminal for wire is a natural brass color, the other is a white color, usually nickel-plated or tinned. The white wire must *always* run to the white terminal. In the case of sockets, the white terminal in turn is always connected to the screw shell and never to the center contact of the socket. Switches for controlling lights, etc., never have white terminals.

Wiring Diagrams—Two wires must run from the starting point to each outlet whether it serves a bulb, motor, or any other electrical device. Imagine, if you wish, that the current flows out over the black wire to the device, through the device, and back to the starting point over the white wire. We will call the starting point the SOURCE, and use a bulb to indi-

Fig. 5-1. This symbol will be used in all diagrams to indicate a bulb.

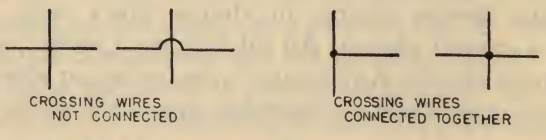


Fig. 5-2. This method will be used in all diagrams to indicate whether crossing wires are connected to each other or not.

cate the device to be operated. We will use the symbol of Fig. 5-1 instead of a picture of a bulb. Note also the method shown in Fig. 5-2 to indicate whether crossing wires are connected to each other or not. In all diagrams the white wire will be indicated by a light line like this ———; black wire,

which is usually known as the "hot" wire, by a heavy line like this ———; and the black wire between a switch and the outlet which it controls by a heavy broken line like this — — —.

The simplest possible diagram is that of Fig. 5-3: a bulb which is always on, with no way of turning it off. Such a circuit is of little value, so let us add a switch. This is very simply done; all we have to do is to make the *black* wire detour to a switch as shown in Fig. 5-4. An open porcelain-base switch is shown so that you can see how it operates; opening the switch is the same as cutting a wire. Fig. 5-5 shows the same circuit but with a flush toggle switch which serves the same purpose but is far neater, handier, and safer because there is no exposed mechanism and because of other differences in construction.

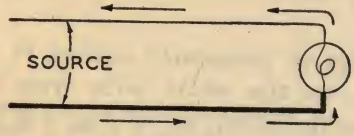


Fig. 5-3. The simplest circuit: a bulb always on.

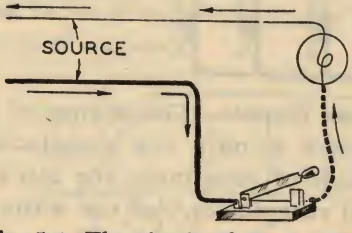


Fig. 5-4. The circuit of Fig. 5-3, plus a switch.

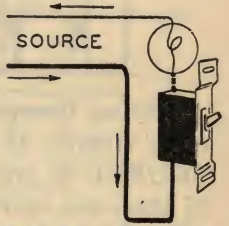


Fig. 5-5. A toggle switch substituted for the open switch.

If several bulbs are to be used, do not make the mistake of wiring them "in series," as the wiring shown in Fig. 5-6 is known, which is impractical except for very special purposes. For example, if one bulb burns out, all go out (as in the "series" type of Christmas tree lights).

Wire them "in parallel," as the scheme shown in Fig. 5-7 is known. The white wire goes to each bulb, from the first bulb to the second and the third and so on; the black wire also runs to each bulb in similar fashion. Each bulb will still light even if one or more of the others is removed. The

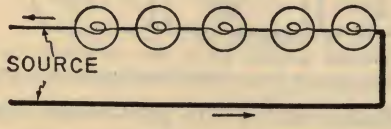


Fig. 5-6. This style of wiring is known as "series" wiring; it is impractical except for very special purposes.

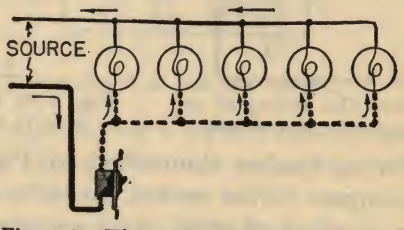


Fig. 5-7. This style of wiring is known as "parallel" wiring, and is used for all ordinary purposes.

switch shown cuts off the current to all the bulbs at the same time. The wiring is most simple: white wire from SOURCE to each socket or outlet: black wire from SOURCE to the switch, and from the switch another black

wire to each of the sockets. This is the way a fixture with 5 sockets is wired.

If each bulb is to be controlled by a separate switch, use the diagram of Fig. 5-8. The white wire always runs from SOURCE to each bulb, the black wire from SOURCE to each switch; from each switch a black wire runs to the bulb which it is to control. Trace the current in over the black wire through each switch separately, along the black wire to the switch, and back from bulb to the SOURCE. Trace it carefully and you will find that each bulb can be separately controlled.

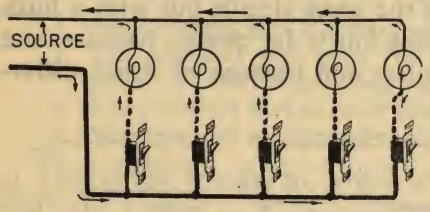


Fig. 5-8. The same diagram shown in Fig. 5-7, but each bulb is now controlled by a separate switch. Note that the white wire runs direct from SOURCE to each bulb.

Wiring Receptacle Outlets—The wiring of plug-in receptacle outlets is most simple. If there is only one receptacle, run the white wire from SOURCE to one side of receptacle, the black to the other, as in Fig. 5-9. If there are several receptacles, run the white wire to one side of the first receptacle, from there to the second, and so on; do the same with the black. See Fig. 5-10; study this picture carefully and you will see that it is the same as the diagram of Fig. 5-7, except that receptacles have been substituted for bulbs, and the switch omitted. In better homes you often see a group of receptacle outlets controlled by a wall switch, so that all the floor lamps, radios, etc., can be turned off with one switch. In that case, connect as shown in Fig. 5-10, but install a switch in the black wire.

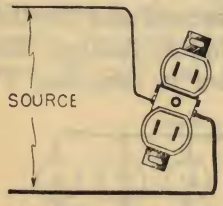


Fig. 5-9. The wiring of receptacles is most simple.

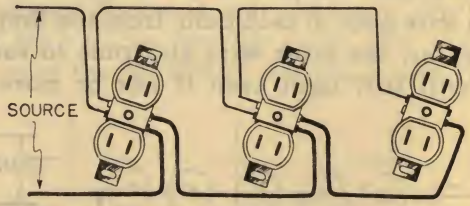


Fig. 5-10. Receptacles usually have two terminals on each side, to make it easy to run wires from one to the next.

Wiring Outlets Controlled by Pull-Chain—Since the pull-chain mechanism is part of the socket, an outlet that is to be controlled only by pull-chain is wired exactly like a receptacle outlet. Simply substitute the pull-chain socket for the receptacle in either Fig. 5-9 or 5-10.

Combining Several Diagrams—When several groups of outlets are to be wired, the two separate wires from each group can be run back to a common starting point, where the wires enter the house, as is shown in Fig. 5-11 where the diagrams of Figs. 5-5, 5-7, and 5-8 have been combined into one.

This would require a very considerable amount of material, and the wires would be much longer than necessary. It is much simpler to merely wire the first group, then to run wires from the first group to the second, and from the second to the third, as is shown in Fig. 5-12, which shows the same three groups but using less material.

The *white* wire may be extended at any point whatever to the next outlet. The black wire likewise may be extended at any point, provided only that it can be traced all the way back to the SOURCE without interruption by a switch. In other words, in these diagrams a black wire can be extended from any black wire indicated by a solid heavy line like this ———, but not from the black wire between a switch and an outlet indicated by a broken line like this — — —. Thus, in Fig. 5-12, A and B are the starting points for the second outlet, and C and D are the starting points for the third outlet (in this particular case, group of outlets).

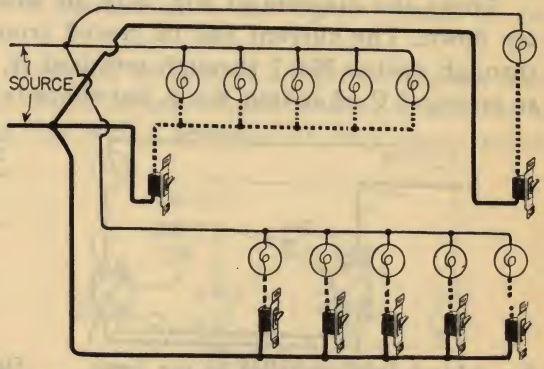


Fig. 5-11. The outlets of Figs. 5-5, 5-7 and 5-8 have been combined into a single group of outlets, in other words here form one circuit. It still uses a great deal of material, and to reduce the amount required, let us rearrange the circuit as the next picture shows.

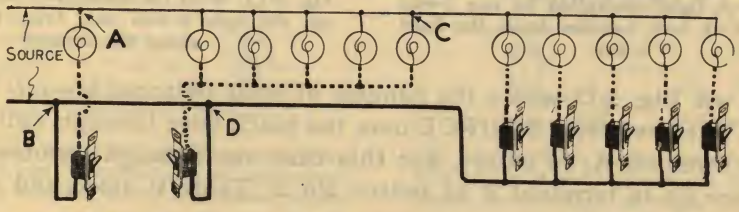


Fig. 5-12. The diagram of Fig. 5-11 rearranged to use less material.

3-Way Switches—The switch used for controlling a light from one point is known as a "single-pole" switch. Very often it is most convenient to be able to turn a light on or off from two different places, as for example, a hall light from upstairs and downstairs, or a garage light from house and garage, or a yard-light from house and barn. For this purpose, switches known as the "3-way" type are used. Despite their name, they will not control a light from three different places, but only two. Such switches have three different terminals for wires, and their internal construction is similar to that shown in Fig. 5-13. In one position of the handle, terminal A is con-

nected inside the switch to terminal B; in the other position of the handle, terminal A is connected to terminal C. Different manufacturers make their 3-way switches in different ways, so that the "common" terminal A is sometimes alone on one end of the switch, sometimes alone on one side. *The common terminal is usually identified by being of a darker color than the others, which are natural brass.*

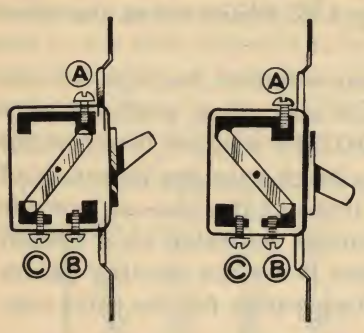


Fig. 5-13. This shows what happens inside a 3-way switch when the handle is thrown from one position to the other. The current always enters by terminal A, leaves by either B or C depending on the position of the handle.

Study the diagram of Fig. 5-14, in which the handles of both switches are down. The current can be traced from SOURCE over the black wire through switch No. 1 through terminal A, out through terminal B, and up to terminal C of switch No. 2, but there it stops. The light is out.

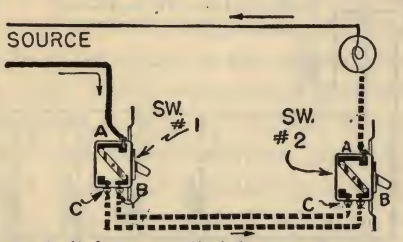


Fig. 5-14. A light controlled by two 3-way switches. With both handles down, the light is out.

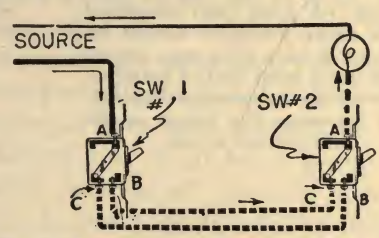


Fig. 5-15. With the handles of both switches up, the light is still out. Trace the current along the arrows.

Next see Fig. 5-15 where the handles of both switches are up. The current can be traced from SOURCE over the black wire through switch No. 1 through terminal A, as before, but this time out through terminal C, and from there up to terminal B of switch No. 2. There it stops and the light is out.

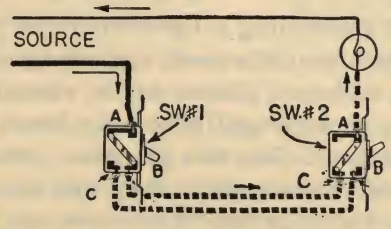


Fig. 5-16. With one handle up, the other down, the light is on. Trace the current along the arrows.

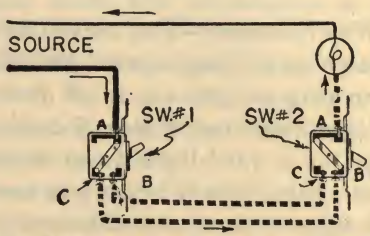


Fig. 5-17. Both handles are the opposite of Fig. 5-16, but the light is still on. Either switch controls it.

Now examine the diagrams of Fig. 5-16 and 5-17, in both of which the handle of one switch is up, the other down. In each case, the current can be traced from SOURCE over the black wire, through both switches, through the bulb, and back to SOURCE. The light in either case is on. In the case of either Fig. 5-16 or 5-17, throwing either switch to the opposite position changes the diagram back to either Fig. 5-14 or 5-15, and the light is out. In other words, the light can be turned on and off from either switch.

The wiring is simple, as these diagrams show. The white wire from SOURCE runs as usual to the light to be controlled. The black wire from SOURCE runs to the common or marked terminal of the first 3-way switch. From the common or marked terminal of the second 3-way switch, runs a black wire to the light. That leaves two unused terminals on each switch; run two black wires from the terminals of the first switch, to the two terminals of the second switch. It makes no difference whether a wire runs from B of the first switch to C of the second as shown, or from B of the first to B of the second.

4-Way Switches—When it is necessary to control a light from more than two points, use a 3-way switch at the point nearest the SOURCE, another at the point nearest the light, and use 4-way switches at each other point.

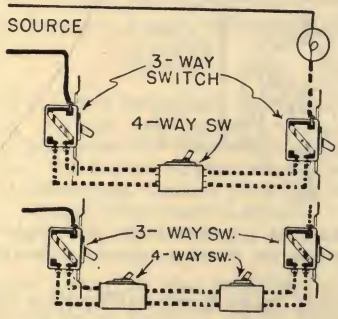


Fig. 5-18. To control a light from more than two places, use 3-way switches at two points, and 4-way switches at the additional points.

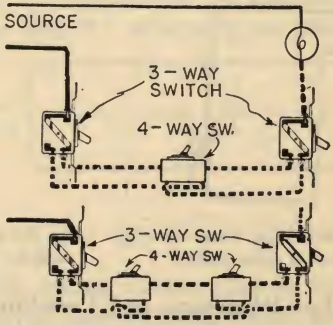


Fig. 5-19. With some brands of 4-way switches, it is necessary to use the diagrams shown here instead of those shown in Fig. 5-18 at the left.

Four-way switches have four terminals for wires, and there are two different methods of internal construction, so that the wiring diagram may be one of two different types. See Fig. 5-18, which you will recognize as the same as Fig. 5-14 except that a 4-way switch has been added between the two 3-way switches. This shows the usual diagram but with some brands it is necessary to wire as shown in Fig. 5-19. You will have to proceed by trial and error until you hit the right combination; no harm can be done by wrong connections, except that the hook-up will not work. If two 4-way switches are required, wire as shown in the lower part of the same pictures.

Pilot Lights—When a switch controls a light that can't be seen from the switch, the light is often left turned on when it should be turned off. Install a pilot light (a small, low-wattage bulb) near the switch, so that both lights are turned on and off at the same time. The pilot light then serves as a reminder that the other light (which can't be seen from the switch) is on. Pilot lights are commonly used in connection with basement and attic lights in homes, with hay-mow lights in barns, and similar locations. Their wiring is very simple as Fig. 5-20 shows. First consider the diagram, disregarding the wires shown in dotted lines, as well as the pilot light itself. It is then the same as Fig. 5-5. Add the wires shown in dotted lines and it becomes the same as the diagram of Fig. 5-7 except that there are only two bulbs instead of five. The white wire runs to both bulbs; the black wire from the SOURCE runs to the switch as usual; the black wire from switch runs to both bulbs, and the diagram is finished.

For this purpose, a combination switch and pilot light similar to that shown in Fig. 5-21 is usually used; the pilot bulb and the switch are combined in one device. The diagram shown in connection with this picture is correct only for one brand; exact diagrams usually come with each piece of merchandise.

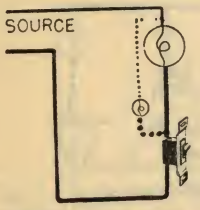


Fig. 5-20. The basic circuit of a pilot light.

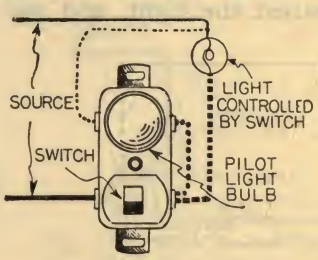


Fig. 5-21. The wiring scheme of a combination pilot light and switch. Another brand might be wired somewhat differently.

Other Diagrams and Combinations—You will have little difficulty making a diagram for any desired combination of outlets and switches, whether single-pole, 3-way or 4-way, if you will bear in mind the principles covered in this chapter. To make any diagram, first locate each outlet where desired and run the white wire (light line like this ———) from SOURCE to every outlet. Then run a black wire (heavy line like this ———) from SOURCE to each outlet that is not to be controlled by a switch. Next run black wire (heavy broken line like this — — —) from each outlet which is to be controlled by a switch, to the switch which is to control it; if 3-way or 4-way switches are involved, run additional ones between the switches which are to control the outlet. Finally, from each switch run black wire (heavy line like this ———) back to SOURCE. You may have to rearrange some of the wires when you have finished, to reduce the amount of wire used, but this will not affect the proper operation of the hook-up.

CHAPTER 6

The Service Entrance

The service entrance consists of the incoming wires and everything else up to and including the service entrance switch. Strictly speaking, it does not include the branch circuit fuses, but since in almost all cases they are inside the same steel cabinet with the service switch, their installation will be included in this chapter.

Selecting Proper Service Switch—Four factors must be considered in selecting the proper switch for any installation. These factors are:

1. The right number of poles (2-pole or 3-pole).
2. The right number of branch-circuit fuses (determine as outlined in previous chapter).
3. The right amperage capacity (30, 60, 100 or 200 amps.).
4. Miscellaneous specifications required in your particular locality. Some switches may be used almost anywhere, but a few localities have their own specifications. Before buying a switch, see your local power company or your R.E.A. officials, give them the manufacturer's name and his number of the switch you propose to use, and you will be told whether it is acceptable or not. If not acceptable, you will be advised what type to buy.

2-Wire or 3-Wire Entrance—The entrance may consist of either two or three wires. If it is the 2-wire type, only 115 volts will be available. In most cases a 3-wire entrance is desirable. See Fig. 6-1 which shows the usual

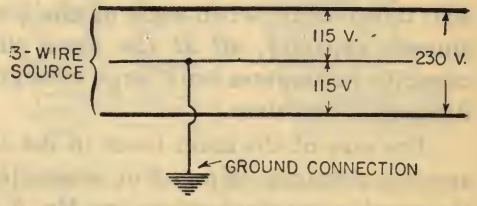


Fig. 6-1. Using only three wires, two different voltages are available. Use the lower voltage or 115 volts for low-wattage devices, the higher voltage or 230 volts for high-wattage devices such as large motors, water heaters, ranges.

3-wire service; the middle wire is grounded, which means that it must be a white wire (out of doors usually weatherproof wire is used which is available only in black color). The other two wires are black. The middle or grounded wire is known as the neutral wire; the other two wires are "hot" wires. The voltage between the neutral wire and either of the two black wires is 115 volts; the voltage between the two black wires is 230 volts.

It is a considerable advantage to have both 115 and 230 volts available, for many devices operate on 230 volts. Most motors of ½ hp. and larger operate on either 115 or 230 volts; the higher voltage is preferable because it permits smaller wires to be used, costing less and causing less voltage drop and wasted power (less voltage drop because at 230 volts a motor consumes only half the amperage it consumes at 115 volts). Electric ranges operate on 115 volts when at low heat, 230 volts when on high heat.

Use a 2-wire service only for the very smallest installations, where it is quite definite that more than two circuits will never be required, and that an electric range will never be added. A summer cottage might be amply served by such a service, but even there a range may be later added, which would then require a new service. It is best to plan on a 3-wire service in every case.

A switch used for a 2-wire service is known as a 2-pole switch. If used for a 3-wire service, it is known as a 3-pole switch.

Number of Branch-Circuit Fuses—In addition to the main fuses, the service switch usually contains also the branch-circuit fuses. Each 115-volt branch circuit requires one fuse, each 230-volt branch circuit requires two fuses. Therefore the usual service switch which contains four branch-circuit fuses may be used for four 115-volt circuits, or for one 230-volt and two 115-volt circuits. If it contains six branch-circuit fuses, it may be used for six 115-volt circuits, or for one 230-volt and four 115-volt circuits, or for two 230-volt and two 115-volt circuits. The method of determining the proper number of branch circuits required for an installation was covered in Chapter 4 (page 36).

30-, 60-, 100- or 200-Ampere Switch—Because you have decided to use, for example, six 15-ampere branch circuits, do not jump to the conclusion that the service switch must have 6 × 15 or 90 ampere capacity. The time will never come when *each* of the six circuits will be carrying its full 15-ampere capacity, *all at the same time.* The service switch must have a capacity in amperes only large enough for the maximum number of amperes flowing at one time.

The size of the main fuses in the switch is determined by the size of the service entrance wires. For example, if a 60-ampere switch is used, but the service entrance wires are No. 6 which have a carrying capacity of 55 amperes, the largest fuse that may be used is the 55-ampere size.

A 30-ampere 2-pole switch is permitted by Code only when not over two branch circuits are involved. A 30-ampere 3-pole switch should be used only when not over 4 branch circuits are involved. Better yet, don't use a 30-ampere switch at all because in a year or two you will be using so many more electrical devices than you at first planned, that the 30-ampere size will probably have to be torn out and replaced with a 60-ampere size, an entirely unnecessary expense.

The 60-ampere 3-pole switch is the smallest size permitted by local codes and power company rules in most localities. This size switch is large enough to handle the usual load plus an electric range and an electric water heater. A 60-ampere switch costs so little more than the 30-ampere that there is no excuse for not using it. Especially on farms, 100-amp. and 200-amp. switches are becoming common.

Miscellaneous Points About Switches—A service switch has a *pole* for each wire, so that a 3-pole switch is used for a 3-wire service, a 2-pole switch for a 2-wire service. However, the neutral wire may not be fused, neither may it be interrupted by a switch; therefore the 3-pole switch has only 2 blades and 2 main fuses, one for each "hot" wire. Accordingly it is known as a 3-pole *solid neutral* switch; likewise a switch for the 2-wire service is known as a 2-pole *solid neutral* and has only one blade, one fuse. The neutral pole in the switch is merely a metal strap with a number of terminals to which the incoming neutral service wire and the outgoing neutrals of the branch circuits are attached.

Many switches are so constructed that, when the door is opened, there are no exposed live terminals, and are then known as "dead front."

Typical Switches—A very commonly used 30-ampere switch with main fuses, and fuses for branch circuits, is shown with its wiring diagram in Fig. 6-2. When the door is opened, clips which are attached to an insulating block mounted on the door, pull out of corresponding clips in the switch proper through openings in an insulating barrier; this opens the main line so that the switch and all circuits are then completely dead. Switches of this type are available in both 2-pole and 3-pole type, with 2 or more fuses for branch circuits. They may or may not be acceptable in your locality; consult your power company or R.E.A. officials. If they are not acceptable, you will be advised which type to buy.

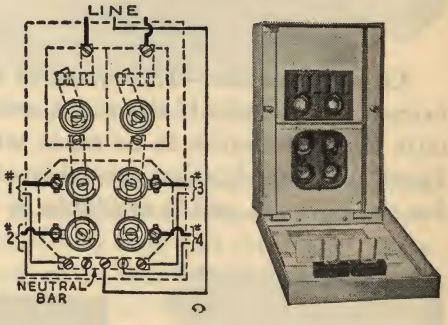


Fig. 6-2. A typical 30-ampere service switch. The cabinet contains two main fuses, also four fuses for four branch circuits. Opening the door kills the circuit. 60-ampere switches cost very little more and should always be used, because the 30-ampere size usually becomes too small within a year or two after installation.

The most popular switch in use today, acceptable almost anywhere, is the 60-ampere 3-pole solid neutral "range combination" shown in Fig. 6-3 with its wiring diagram. The cabinet contains the two main cartridge fuses which may be from 35 to 60 amperes (these sizes all have the same dimensions), two more cartridge fuses again from 35 to 60 amperes to protect a 230-volt branch circuit serving a range (or other heavy load such as a water heater or large motor) and four plug fuses protecting four 115-volt branch circuits. There is no switch proper with blades operated by a handle, but the circuit is opened by removing the main fuses, which are mounted on an insulating block which pulls out as shown in the picture. When the insulating block is

pulled out, there are no exposed live parts on the switch, no possible danger from shock. The fuses are changed while the insulating block is in your hand.

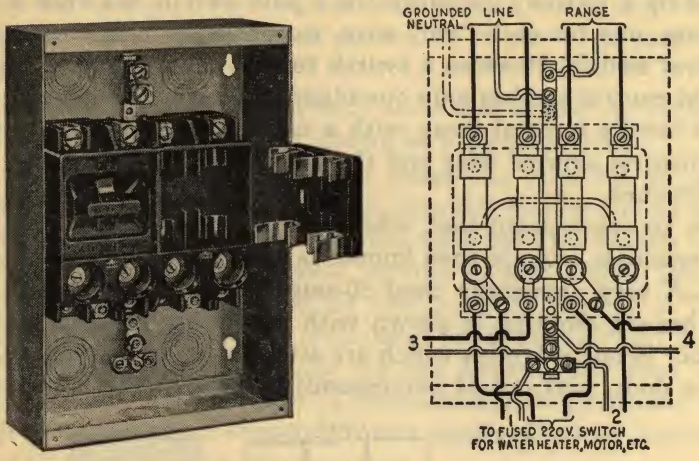


Fig. 6-3. A very popular 60-ampere "range combination" service switch (less cover). It contains two main cartridge fuses, two more cartridge fuses for range or large motor, and four plug fuses for four branch circuits.

Circuit-Breakers—If, instead of a fuse, a circuit-breaker is used for each branch circuit, and if there are not over six branch circuits, the Code permits the installation to be made without a main switch and without main fuses. A circuit-breaker assembly of the type shown in Fig. 6-4 is designed for the purpose, and is available in either surface type, or flush type which

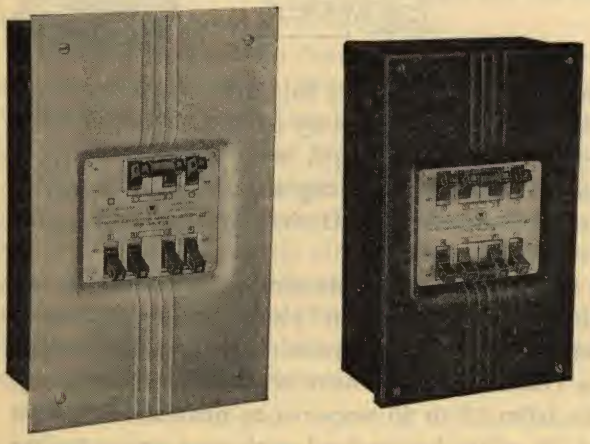


Fig. 6-4. The really modern home is fuseless. This attractive circuit breaker, mounted in kitchen or hallway, eliminates all fuses. Protection is increased, convenience added. The picture shows both the flush and the surface types.

may be mounted in the wall with the front flush with the wall. Circuit breakers are becoming very popular because they do away with the bother of fuses, afford protection for the circuits, and also permit temporary overloads which would blow ordinary fuses (but not time-lag fuses).

Location of Service Switch—The switch with its branch circuit fuses should be located as close as possible to the point where the entrance wires come into the building. Formerly the usual location was in the basement, but this is most inconvenient when fuses blow. Moreover, the devices which use the most power are usually flatirons, toasters and similar devices in the kitchen. Therefore, it is sensible to let the service entrance wires enter the

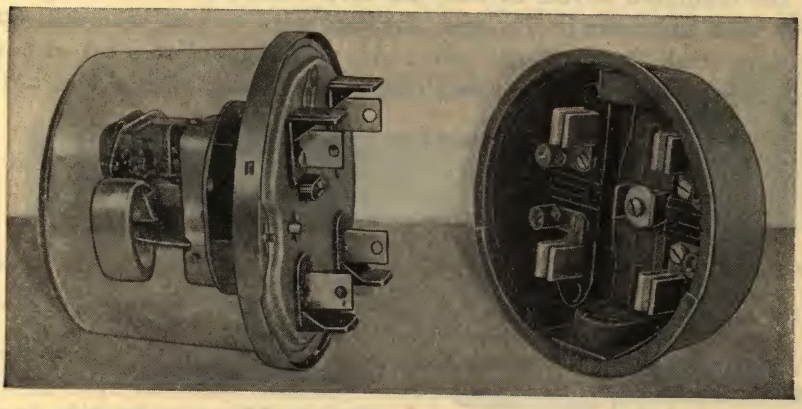


Fig. 6-5. A typical outdoor weatherproof kilowatt-hour meter and its socket.

building at some point in the kitchen or pantry, and to locate the service switch at that point. Less material will be used, and since the flush type cabinets of switches and circuit-breakers are entirely neat and attractive, there is no reason why they should not be mounted in that convenient location.

Fig. 6-6. An insulator rack.

Fig. 6-7. Screw-point insulators may be used in place of the rack shown in Fig. 6-6.

Location of Meter—In practically all cases, the outdoor type of meter is used. The base or socket is usually furnished by the power company but installed by the contractor, in a location specified by them. Meter and base are illustrated in Fig. 6-5. Usually the meter is installed on the outside of the building about 5 to 7 feet above ground level. On farms the meter is often located on a pole in the yard; this construction will be covered in Chapter 15.

Service Insulators—The incoming wires are anchored on the building on service insulators, as high up as possible, so that there is plenty of clearance below the wires. In most localities racks of the type shown in Fig. 6-6

are used; select a type with the insulators at least 6 inches apart. In some localities those with 8-inch spacing are required. In other localities simple screw-point insulators of the type pictured in Fig. 6-7 are permitted.

Bringing Wires Into Building—Service entrance cable is generally used to bring the wires into the building. It is illustrated in Fig. 6-8. One of the wires is not insulated and consists of a number of fine wires wrapped around the insulated wires. In use, the bare wires are twisted together to make one wire, as shown in Fig. 6-9. The bare wire may be used only for the grounded neutral. Over all the wires comes a flat spiral steel armor, for mechanical protection. In some localities cable is used which does not have

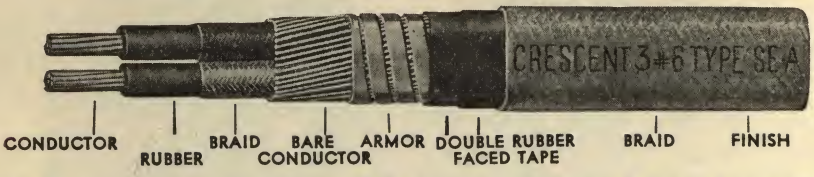


Fig. 6-8. In service entrance cable one of the wires is not insulated, but is bare, and wrapped spirally around the insulated wires. The picture shows 3-wire cable.

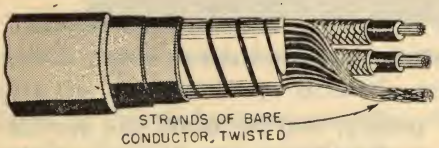


Fig. 6-9. When using the cable, the separate strands of the bare wire are gathered into a bunch making one larger wire.

this steel tape; both types are approved by Underwriters. Over all comes a fabric braid or outer protective layer. This usually has a painted finish which in turn may be painted to match the building. Use cable with No. 8 wires for a 30-ampere switch; with No. 6 wires for a 60-ampere switch; with No. 4 or 2 wires for a 100-ampere switch.

The cable is attached to the building with straps, one type of which is shown in Fig. 6-10. At the top end use a service head, one type of which is

Fig. 6-10. Attach service entrance cable to the building with straps shown.

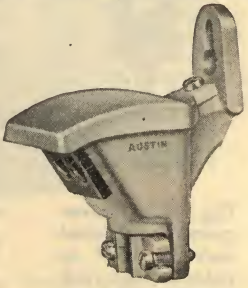


Fig. 6-11. The service head shown prevents rain from entering the cable at the cut end.

shown in Fig. 6-11. This is merely a device to keep the rain from entering the cable. It clamps to the cable and an insulating block separates the individual wires.

Wherever the cable enters a switch cabinet or a meter base, it must be securely attached with a connector. Out-of-doors a weatherproof connector must be used; a common type is shown in Fig. 6-12. The connector consists of a body and a heavy block of rubber, and a clamping nut or cover which presses the rubber against the cable, making a water-tight joint. Indoors a less expensive connector of the type shown in Fig. 6-13 may be used instead.

At the point where the cable enters the building, steps must be taken to prevent rain water from following the cable into the building. Use a sill

Fig. 6-12. Where cable is attached outdoors to a meter base or other device, use a water-tight connector.

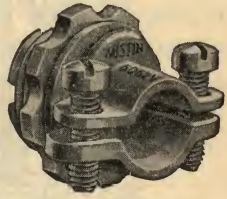


Fig. 6-13. A non-water-tight connector.

plate which is shown in Fig. 6-14. It is a stamped or cast cover, which is mounted over the cable where it enters the building. Weatherproof compound is usually furnished with the plate; pack it tightly in all openings between the cable and the sill plate.

To install service entrance cable, cut a length to reach from the meter base to a point a foot or so below the service insulators, plus about 3 feet for connections. Attach the service head at the top, letting the separate

Fig. 6-14. A sill plate is used at the point where the cable enters the building. Sealing compound that comes with the plate is packed around the cable, to prevent rain from following the cable into the building.

wires stick out of the head about 3 feet. The power company will attach their wires to these ends. At the bottom end, attach the conductors to the terminals in the meter socket, as shown in the diagram of Fig. 6-15, which also shows the next length of the cable running on to the service switch. A weatherproof connector is used at top and bottom of the meter socket. The finished job is shown in Fig. 6-16.

Entrance with Conduit—Instead of service entrance cable, separate rubber-covered wires inside of conduit may be used. If it is a 2-wire entrance, use one black wire, one white; if it is a 3-wire entrance, use two black wires, one white. The wires will be either No. 8, 6, 4 or 2, as in the case of service entrance cable.

If two or three No. 8 wires are to be installed, use ¾-inch conduit. If three No. 6 wires are to be used, use 1-inch size. If three No. 4 or No. 2 wires are to be used, use 1¼-inch conduit.

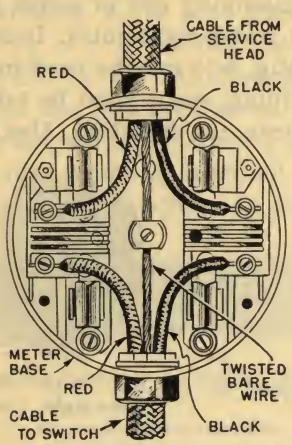


Fig. 6-15. How wires are attached to the meter base or socket. The bare, uninsulated wire is always attached to the neutral center contact.

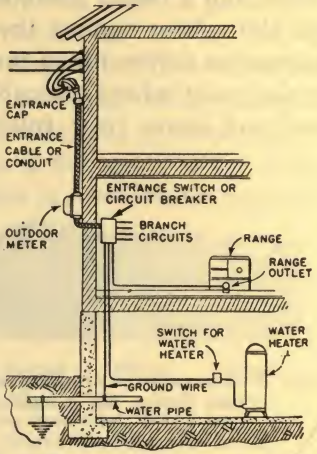


Fig. 6-16. Completed installation of the service entrance, including the ground wire which is explained in detail later.

Conduit is steel pipe which looks like water pipe, but is different in several important respects. Cut pieces as long as required, thread them, and ream them in the manner outlined in Chapter 10. Attach a service head at the top, similar to that shown in Fig. 6-17 and threaded to fit directly on the conduit. At the point where the conduit is to enter the house, use an entrance ell, one type of which is shown in Fig. 6-17. This has a removable cover which makes it possible to help the wires around the sharp bend, while pulling them into the conduit.

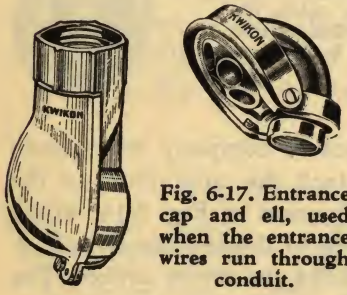


Fig. 6-17. Entrance cap and ell, used when the entrance wires run through conduit.

The conduit must be securely anchored to the service switch, both to make a good mechanical joint, and to provide a good ground between the switch cabinet and the conduit for grounding purposes. Use a locknut and bushing as outlined in Chapter 10.

After the conduit itself is completely installed, pull the wires into it. For the relatively short lengths involved, the wires can usually be pushed in at the top and down to the meter socket; from there, other lengths are pushed through to the inside of the house. If the conduit is quite long or has bends in it, use fish wire; a length of galvanized clothes-line or similar

wire will serve the purpose. Push the fish wire into the conduit, attach the electrical wires to it, and pull them in.

Grounds—Every installation of the type covered by this book must be grounded. This is done by running a wire from the incoming neutral wire (usually at the point where it attaches to the neutral strap in the service switch), to a pipe or other object which is always in good contact with the earth. The cabinet of the service switch becomes automatically grounded because the neutral wire is attached to it through the neutral strap, which is not insulated from the cabinet. The armor of armored cable, if that is used for wiring the house, or the conduit of a conduit system, automatically are also grounded because they also are attached to the service switch. The technical reasons for grounding are fairly complicated, but a *good, carefully installed ground connection is absolutely necessary if the completed installation is to be safe.*

Ground Connection—In city wiring, the ground wire usually runs to the city water system in as direct and short a line as possible, from the service switch to the cold water pipe, to which it is attached by means of a ground clamp. On farms, an "artificial ground" is used, which consists merely of a pipe or rod driven at least 8 feet into the ground. Steel rods with an outer layer of copper ("Copperweld") are preferable; the outer diameter must be ½ in. or more. The Code permits galvanized rods or pipes at least ¾ in. in diameter, but the copper is better.

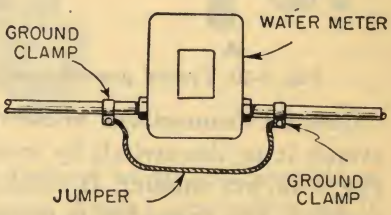


Fig. 6-18. In city wiring, place a jumper around the water meter, as shown. Use same size wire as you use for the ground.

Water Meters—In city wiring, a jumper should be installed around the water meter as shown in Fig. 6-18. Use two ground clamps and a piece of wire the same size as used for the ground. This prevents the ground from being made ineffective if the water meter is removed; some water meters also have insulating joints.

Ground Wire—Although there is no objection to using insulated wire, it is more common practice to use bare, uninsulated wire for the ground. Either No. 8 or 6 is usually used. If No. 8 is used, it must be protected by running through conduit or armor; a common type is shown in Fig. 6-19. If No. 6 is used it does not need to be protected by conduit or armor, but must be attached to the surface over which it runs, staples being used for the purpose. Some inspectors require even No. 6 to be protected by conduit, or armor as shown in Fig. 6-19.

The ground wire is attached to the water pipe or ground rod by means of a ground clamp, of which several types are shown in Fig. 6-20. Galvanized iron clamps should be used only with galvanized pipe grounds. That at A is used in connection with armored ground wire of the type shown in Fig. 6-19; the copper wire is fastened under the large terminal screw, and the armor is secured by the clamp provided for the purpose. That at B is similar but larger to accommodate conduit which is sometimes used as protection for the ground wire. If a copper-coated ground rod is used, be sure to use a clamp made of brass or bronze; a typical one is shown at C of Fig. 6-20.

Fig. 6-19. Armored ground wire. The wire is not insulated.

A B C

Fig. 6-20. Typical ground clamps. Each one serves a somewhat different purpose.

Ground Connections at Service Switch—If armored ground wire is used attach it to the switch by means of a connector similar to that shown in Fig. 6-13, but smaller. If conduit is used attach it by means of locknut and bushing. The ground wire proper is attached to the neutral bar of the service switch—the same neutral bar or strap to which the incoming neutral wire is attached.

When service entrance cable is used to bring the incoming wires into the building, the grounding is most simple as A of Fig. 6-22 shows. Only the white wires are shown in this diagram.

When conduit is used to bring the incoming wires into the building, the Code requires that a grounding bushing (shown in Fig. 6-21) be used instead of the ordinary bushing which is usually used. This grounding bushing has a clamp into which it is necessary to fasten a short piece of wire the same size as the ground wire; the other end goes to the neutral bar or strap. If conduit is used to protect the ground wire, a grounding bushing is also used on that, again with a jumper to the neutral bar of the switch. B of Fig. 6-22 shows the construction.

Using Artificial Ground—The procedure above is complicated a bit when the ground rod is located outside of the building in which the service switch is located. In that case, the ground wire must be brought from the inside to the outside of the building.

When using service entrance cable, simply bring the ground wire out through the same opening through which the service entrance cable enters the building. The sill plate has a small opening near the bottom for this ground wire.

Fig. 6-21. A grounding bushing.

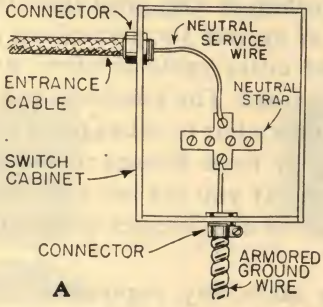


Fig. 6-22. Typical ground connections, at left when entrance cable is used, at right when conduit is used. Only the white wire is shown.

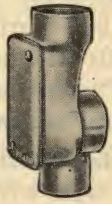


Fig. 6-23. A grounding elbow, used with conduit entrance when an artificial ground is used.

When using conduit, use a grounding ell instead of an ordinary ell at the point where the conduit enters the building. Such a grounding ell is shown in Fig. 6-23. The ground wire can then be brought out through the opening at the bottom.

Check to see what method is used in your locality; follow that method.

CHAPTER 7

Four Wiring Systems

In residential and farm wiring, four different systems are in common use. They are: (1) Non-metallic sheathed cable, (2) Armored cable, (3) Knob-and-tube, (4) Conduit.

Which System to Use?—Separate chapters will cover the details of each system. Local codes sometimes prohibit one or more of these systems. In general non-metallic sheathed cable is the most common, especially on farms. Where there is a city water system for grounding purposes, armored cable is more common. In larger cities cable is often prohibited for *new* buildings, and conduit required instead. The knob-and-tube system is almost unknown in some parts of the country but in other parts is extensively used, especially in the southwest, roughly from Kansas to Texas, and also on the Pacific Coast. Follow local custom. If you are not sure, consult your power company, the electrical inspector, or the Project Supervisor in the case of R.E.A. jobs.

Many things are done in the same way regardless of which system is used, and these will be explained in this chapter. Study them well, for they are the foundation for all systems and will not be repeated later.

All explanations will be for "new work," or the wiring of a building while it is being built. The basic principles for "old work," or the wiring of a building after it is built will be covered in a later chapter. There is little difference except that "old work" has more problems of carpentry. Study "new work" well in order to better understand "old work."

Outlet and Switch Boxes—It is not practical to use switches and receptacles fastened to the wall without further protection. Joints and splices in wire and cable, if not given special protection, would be unsightly—and dangerous as well. Therefore the Code requires that every joint in cable, every switch, every outlet be housed in a steel box. Every fixture is mounted on a box. The boxes are known as switch boxes or outlet boxes, depending on their particular shape and purpose. Most boxes have a galvanized finish, and these may be used anywhere. Those with a black enamel finish may be used only indoors. R.E.A. requires galvanized.

Non-Metallic Boxes—Boxes made of bakelite, porcelain or other insulating materials are becoming quite common, especially for farm use. They may be used only with non-metallic cable or knob-and-tube wiring. See page 72.

Switch Boxes—Every switch and receptacle must be housed in a box; the most common is the type shown in Fig. 7-1. Note the small holes used to nail the box to the studding. There are also mounting brackets on the end so that the box can be mounted on wooden or similar supports. There

are two "ears" with tapped holes for screws to hold switches and similar devices mounted on them. The Code requires that such boxes must have a depth of at least 1½ inches; the deeper ones (from 2¼ to 2¾ inches in depth) are handier and more generally used.

A switch box is usually considered the handiest type of box for mounting fixtures of the wall bracket type. Locate one at each point where a wall bracket is to be used.

Each box holds one switch, receptacle or similar device. When two or more switches are to be mounted side by side, two or more boxes can be

Fig. 7-1. A typical switch box, used to house switches, receptacles and similar devices. The sides are removable.

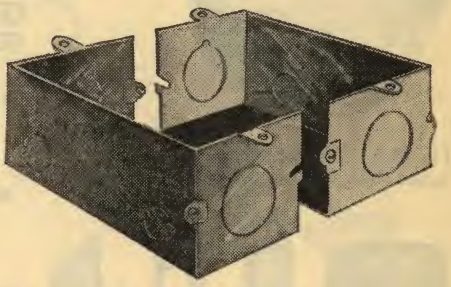


Fig. 7-2. Two single boxes are easily and quickly changed into one larger "2-gang" box. Larger boxes of 3 or 4 or more gangs are made in the same way.

changed into one "2-gang" or larger box by simply throwing away one side of each box and fastening the boxes together, as Fig. 7-2 shows.

Knock-outs—Wires and cables must be brought into the box. For this purpose, "knockouts" are provided; these are sections of metal sufficiently loosened so that they can easily be removed to form openings. These sections are knocked out by placing a screwdriver at the proper point and striking it a stiff blow. In many cases "pry-outs" are provided—these are knock-outs, each with a narrow slot punched into it. Place a screwdriver into the slot, twist out the knockout.

Outlet Boxes—Fig. 7-3 shows the most common outlet box. It is octagonal in shape and comes in two sizes: 3¼ and 4 inch. The larger box is the more common, being much handier because it is more roomy, which permits more wires to be used, does away with cramping, and in general speeds up the work. All boxes are required by Code to be at least 1½ inches deep if used for "new work."

Outlet boxes must always be covered. A great many different covers are available and common ones are shown in Fig. 7-4. At *A* is shown a blank cover used when a box is merely used to hold a splice or tap. At *B* is shown a drop cord cover; the opening for the drop cord is fitted with a smooth bushing to eliminate sharp edges. At *C* is shown a spider cover used to mount

surface-type switches. At *D* is shown a cover with a duplex receptacle. At *E* is shown a keyless receptacle for a bulb and at *F* a similar one with a pull-chain. Many other styles are available.

Other Outlet Boxes—Boxes 4 inches square are sometimes used, having

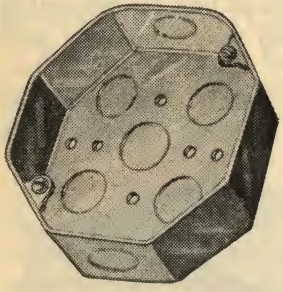


Fig. 7-3. The most common outlet box is the octagonal type.

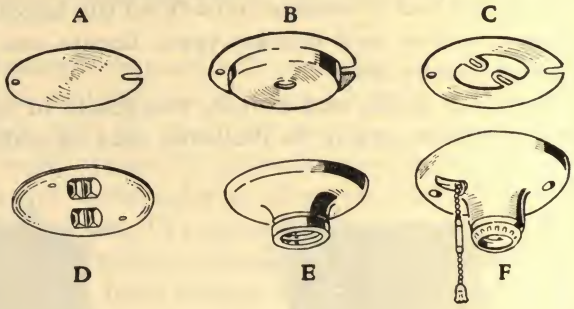


Fig. 7-4. Every outlet box must be covered. Above are shown the most common types of covers.

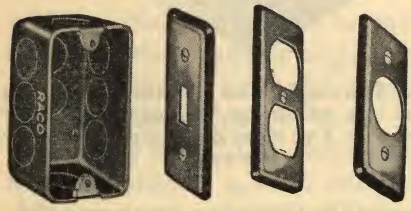


Fig. 7-5. The box shown at left is known as a "utility box" or "handy box." Use it mounted on the surface of walls, as for example, in basements or barns. Neither the box nor the covers have sharp corners.

the advantage of being more roomy than the octagonal variety. They are used mostly for commercial work.

If an ordinary switch box is mounted on the surface of a wall, as in a garage or barn, the sharp corners on both the box and plate are quite a nuisance. In such locations use a box with rounded corners, known as a "utility-box" or "handy-box." This box is shown in Fig. 7-5 with suitable covers for switches and receptacles.

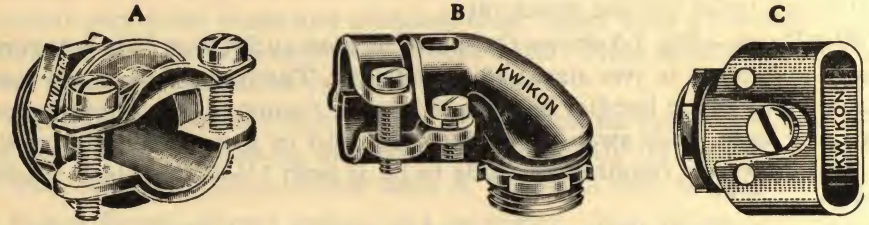


Fig. 7-6. Connectors are used to anchor cable to boxes. They also prevent injury to the cable at the knockout.

Connectors—When cable of any style is used for wiring, the Code requires that it be securely fastened to each box where it enters the box. There are many kinds of connectors for this purpose; an assortment of them is

shown in Fig. 7-6. The connector at *A* is used for ordinary purposes, that at *B* for a sharp 90° turn and that at *C* when two pieces of cable must enter the same knockout. The connector is first fastened to the cable, then slipped through the knockout, and the locknut then driven home solidly on the inside. See Figs. 7-7 and 7-8.

Some boxes have built-in clamps that securely hold the cable entering the box, so that separate connectors don't have to be used. Typical boxes of this kind are shown in Fig. 7-9.

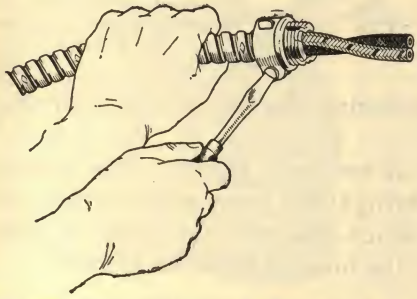


Fig. 7-7. The connector is first attached to the cable by means of a set screw.

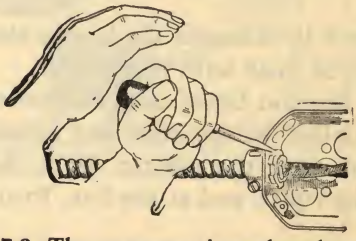


Fig. 7-8. The connector is anchored to the box by means of a locknut inside the box.

Round Boxes—Instead of using boxes which are octagonal or square, round boxes may be used instead, if preferred. A typical one is shown in Fig. 7-10. Such boxes nearly always have cable clamps because connectors (or locknuts and bushings for conduit) cannot be used on a rounded surface but only in the flat bottom.

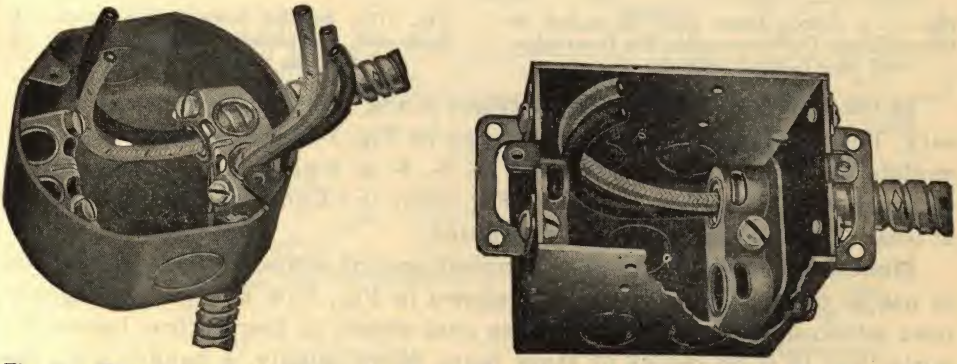


Fig. 7-9. When using boxes of the type shown above, separate connectors are not needed. The cable is anchored by special clamps which are part of the box.

Fixture Studs—A fixture stud is shown in Fig. 7-11. Mount one in the bottom of the box with stove bolts, if a fixture is later to be installed on that particular box. This is unnecessary if a hanger described a little later is

used to support the box. Some styles of boxes, as for example the one shown in Fig. 7-10, have a fixture stud as a permanent part of the box.

Mounting Switch Boxes—There are many ways of mounting a switch box. The simplest way is to nail it to one of the studs, if there happens to be one at the right location, as shown in Fig. 7-12. The important point to watch is to mount the box so that after plastering the front edge of the box will be flush with the plaster.

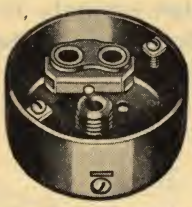


Fig. 7-10. Round boxes are preferred by some, especially in "old work" or the wiring of buildings after they are completely built.

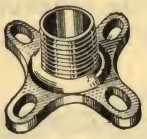


Fig. 7-11. The fixture stud shown is mounted in the bottom of the box by means of stove bolts. The fixture stud later supports the fixture.

Bracket boxes used as shown in Fig. 7-13 are much handier. The bracket is nailed to the stud and automatically brings the front edge of the box flush with the plaster. Note the trough which supports the ends of those laths which end at the box. Projections on the bracket hold the plaster.

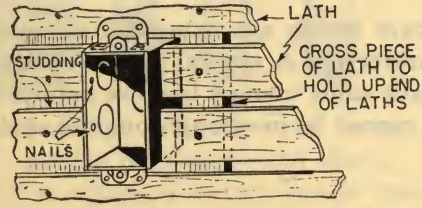


Fig. 7-12. Switch boxes may be nailed to the studding. Use care so that the front edge will later be flush with the plaster.

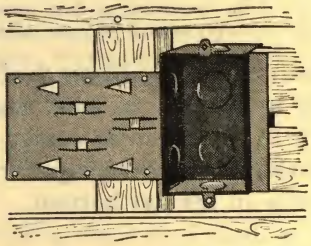


Fig. 7-13. Bracket boxes are automatically flush with the plaster. Note the trough for holding up ends of lath.

If the box is to be mounted between studs, mounting straps are necessary. The ready-made steel straps shown in Fig. 7-14 are handy and accommodate not only a single box but a 2-, 3-, 4- or 5-gang box as well. Strips of wood may be used as shown in Fig. 7-15; the Code requires them to be at least ⅞-inch thick and rigidly mounted.

Mounting Outlet Boxes—The simplest way of mounting an outlet box is to use an offset hanger of the type shown in Fig. 7-16. If a plain hanger is used which does not have the fixture stud shown in the picture, fasten the outlet box to it by means of stove bolts. More usually, a hanger with the fixture stud is used. To attach a box, remove the center knockout in the bottom, slip the fixture stud into this opening, and tighten the locknut over the fixture stud, inside the box. The hanger is then nailed to the joists of the building as shown in Fig. 7-17. A fixture may later be mounted on the fixture stud as shown in Fig. 7-18.

Hangers come in two types: shallow and deep. Use the shallow type for all wiring except conduit; it will bring the front edge of the box flush with the plaster. Use the deep variety when wiring with conduit. The front edge of the box will then not be flush with the plaster, but below it; therefore install on top of the box a "plaster ring" cover, shown in Fig. 7-19, which will then be flush with the plaster. Plaster rings are available only for 4 inch octagonal or square boxes. The opening in the ring however is 3¼ in. size so 3¼ in. covers must be used with it.

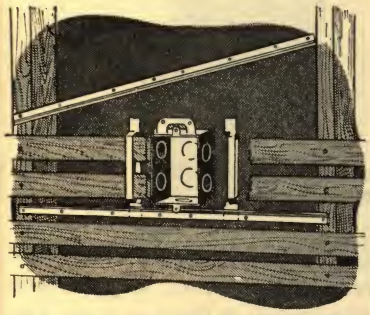


Fig. 7-14. Metal mounting strips permit one or more boxes to be mounted between studs. Special straps hold up the laths which end at the box.

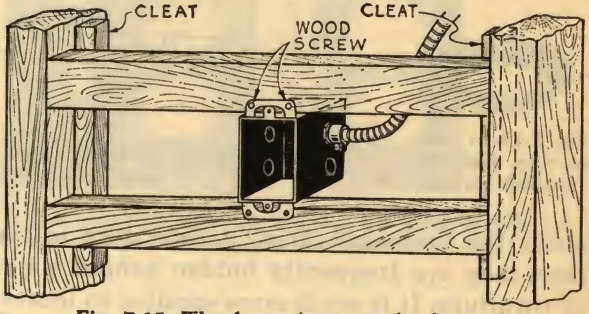
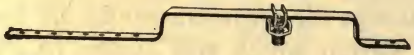
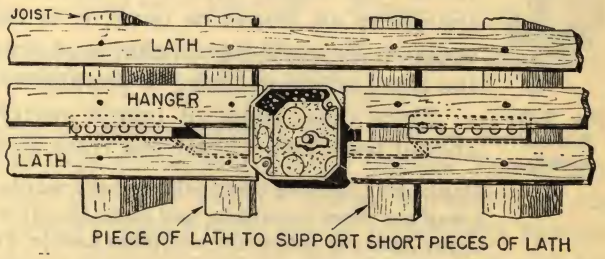


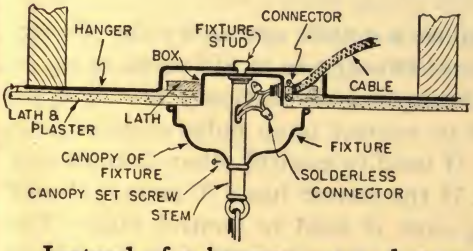
Fig. 7-15. Wooden strips may also be used to support boxes, provided the strips are at least ⅞th inch thick.



← Fig. 7-16. An offset bar hanger.

→ Fig. 7-17. This shows how a bar hanger is used. It automatically brings the front of the box flush with the plaster.





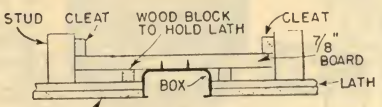
← Fig. 7-18. This shows how a fixture is mounted on the box, and supported by the fixture stud, after the installation of Fig. 7-17 is made. The stem of the fixture is threaded to fit the fixture stud.

Instead of a hanger, a wooden mounting board may be used instead. It must be at least ⅞-inch thick and is installed as shown in the two views of Fig. 7-20.

Wiring at Boxes—Regardless of the particular system used, let from 6 to 8 inches of wire stick out at each box. Any extra length can easily be cut off, but if the wires are too short it is hard to do good work.

Location of Switch Boxes—Boxes for switches should be located near doors, so that they can be easily found as the door is opened; consider which way the door is to swing. The right height is about 48 inches above floor level. Switch boxes for receptacle outlets are usually located a few inches

Fig. 7-19. A plaster ring, used with conduit wiring.



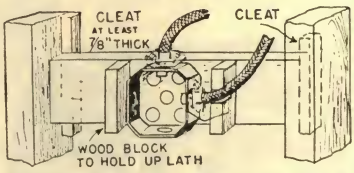


Fig. 7-20. Wooden mounting strips, at least 7/8 th inch thick, may also be used in supporting outlet boxes.

above the baseboard. Don't locate them in the middle of a long wall, for then they are frequently hidden behind a davenport or other large piece of furniture. It is much more sensible to locate them near a door or near the end of a wall where it is easy to get at them, not only for floor lamps and radios but also for vacuum cleaner.

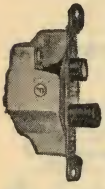


Fig. 7-21. A push switch.

Selection of Switches—The old-fashioned push switch of Fig. 7-21 is seldom used today except for replacements in old installations. The toggle type of switch which was shown in Fig. 2-1 should by all means be used; it is neater, easier to operate, and cheaper. You will have a choice of brown or ivory colored handle; the ivory is fast growing in popularity as it is especially attractive.

Since three types of toggle switches are in common use, you should learn how to tell one from another.

Single-pole has two terminals, and the words ON, OFF on handle.
3-way has three terminals, and plain handle without ON, OFF.
4-way has four terminals, and plain handle without ON, OFF.

T Rating—An ordinary switch is given a double rating by the Underwriters, so that it can be used either up to 10 amperes at 115 volts, or up to 5 amperes at 230 volts. Moreover, the rating may be ordinary or "T" type. A switch with ordinary rating if used to control lamp bulbs may be used only up to *half* of its amperage rating; if used to control other devices may be used up to its full amperage rating. If the switch has a T rating, it may be used up to its *full* amperage rating even if used to control bulbs. The type with the T rating is the better switch, and is the only type permitted by the R.E.A. for farm use. All approved switches have the words "Und. Lab. Insp." stamped on the metal strap. The ones with ordinary rating are

further marked "10 A 125 V—5 A 250 V," while those with the T rating have the letter T after the rating so that it reads "10 A 125 V—5 A 250 V—T."

Wall Plates—Typical plates are shown in Fig. 7-22; they are available in bakelite, brass, glass and other materials. The bakelite is by far the most popular type today, and comes in a choice of brown or ivory color, the latter being especially attractive. Use the kind you like best.

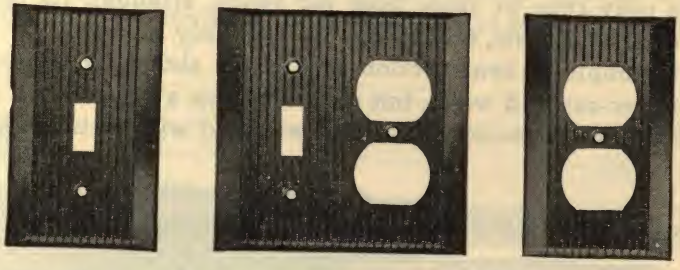


Fig. 7-22. Switches and receptacles are covered with neat plates which are made of bakelite or similar materials. Metal plates are not popular today.

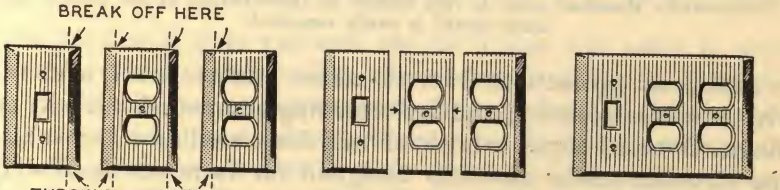


Fig. 7-23. A new style plate which makes it possible to make 2-gang or larger plates in any desired combination, out of single plates.

For two or more switches or similar devices used side by side, use a 2-gang or larger plate of the type shown in the same picture. It has been hard to find 3-gang and larger plates in dealers' stocks, especially in odd combinations, but there is now available a new type of *single-gang* bakelite plate so made that a strip can be easily broken off either side. Two separate plates, each with one strip broken off, are exactly the right size to make a 2-gang plate. Plates of any number of gangs can be made in the same way, in any desired combination no matter how unusual. Fig. 7-23 shows how this is done.

CHAPTER 8

Wiring with Non-Metallic Sheathed Cable

Non-metallic sheathed cable costs less than other kinds of cable in common use, is light in weight and very simple to install; no special tools are needed. Accordingly it is very popular. The Code recommends it for all locations where an especially good ground connection is not found. That makes it the only type of cable used for farms, although its use is quite general for other locations, too. It may be used only indoors.

It is quite simple in construction as Fig. 8-1 shows. It consists of two (or three) rubber-covered wires, but each wire has a paper braid instead of the usual cotton braid; each wire is also wrapped with a thick spiral paper

Fig. 8-1. Non-metallic sheathed cable is very simple in construction as the picture shows. The outer braid is easily removed.

tape for additional protection. Over all comes a fabric braid which is saturated with moisture-resisting and fire-retarding compounds; it will not support a flame. Over all comes a layer of wax for cleanliness in handling. (A new type of construction specially designed for farm use is described on page 112.

Fig. 8-2. This cable ripper removes the fabric cover of non-metallic sheathed cable in a jiffy. It also serves as a wire gauge.

Only a jack-knife is needed to remove the outer cover. Cut a slit parallel with the wires; be careful not to damage the insulation. The cable ripper shown in Fig. 8-2 is very handy for the purpose; it is faster than a knife and can't possibly damage the insulation. The outer cover is usually removed for about 8 inches.

Installation—Cable should never be bent sharply, otherwise the outer fabric cover will be damaged and openings will result. The Code says that all bends must be gradual so that, if continued in the form of a complete circle, the circle would be at least 10 times the diameter of the cable. The cable must always run in a single continuous piece from one box to the next —no splices except inside boxes.

The cable must be fastened to the surface over which it runs every 4½ feet, also within 12 inches of every outlet box or switch box. Straps of the general type shown in Fig. 8-3 are used for the purpose. Do not use staples of any kind because there is too much danger of damaging the cable by hitting staples too hard.

If the cable in the finished job is not exposed but concealed, there are no restrictions as to how it is to run. It may follow the side of a stud or joist, anchored as above outlined, or at right angles to such timbers through bored holes.

Fig. 8-3. Support cable at least every 4½ feet. Use straps shown.

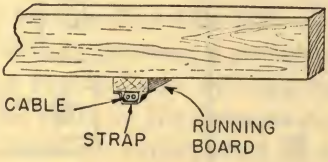


Fig. 8-4. Exposed cable running across timbers must be protected by running-board, which prevents damage.

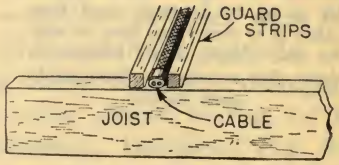


Fig. 8-5. In attics, guard strips may be used. If run through bored holes, no further protection is needed.

If the finished wiring is exposed, see to it that the cable is protected against later mechanical injury. The easiest way is to run it along the side of a stud or joist. If run at right angles to such timbers (unless the cable runs through bored holes) a running-board must first be installed as shown in Fig. 8-4. The Code is not specific as to the size of this running-board but the so-called "1 by 2" is fine for the purpose. The cable may never be run across free space, must follow the surface of the building except when mounted on the running-boards. In unfinished basements, it may be run through bored holes through the centers of joists, except that cables No. 8-3 or 6-2 or heavier may be mounted directly on the bottoms of joists without a running-board. In accessible attics, cable may run at an angle to joists if protected by guard strips at least as high as the cable, as shown in Fig. 8-5; a running-board costs less and takes less time to install.

Where it runs through a floor in exposed work, it must be protected by conduit or other pipe extending at least 6 inches above the floor. In the wiring of hay-mows in barns, special care must be used; see Chapter 15 on farm wiring.

Plan the Installation—Before you can do any actual wiring, you must make a plan. Decide upon the location of each outlet, each switch. Be generous in the number of outlets and switches; plan an *adequate* installation as described in Chapter 2; remember that it costs much more to add an outlet later, than it does to include it in the original job.

Which Outlets on Which Circuit?—Your first idea may be to put all the outlets of your basement on one circuit, all the outlets of the first floor on

the next circuit, those of the second floor on still another circuit, and so on. If you do this and a fuse blows, what happens? An entire floor will be in darkness. It is much more sensible to have different parts of any floor on two different circuits; then at least part of each floor will still be lighted even if the rest of that floor is dark.

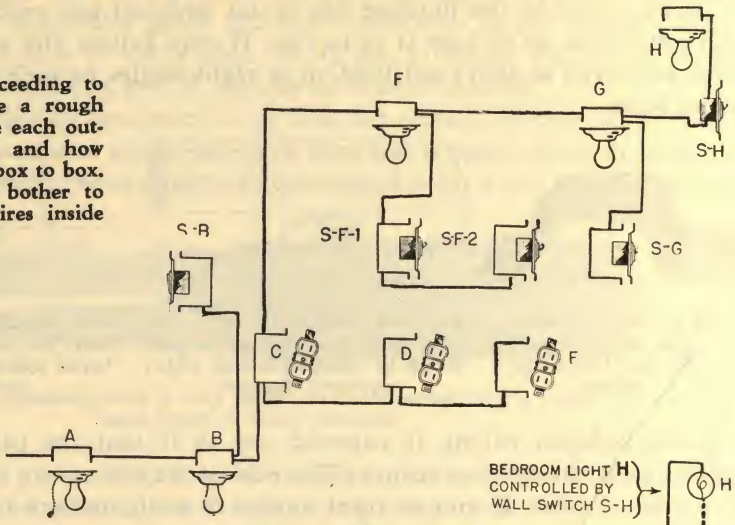


Fig. 8-6. Before proceeding to do any wiring, make a rough layout showing where each outlet is to be located, and how cable is to run from box to box. At this stage, don't bother to show the separate wires inside each cable.

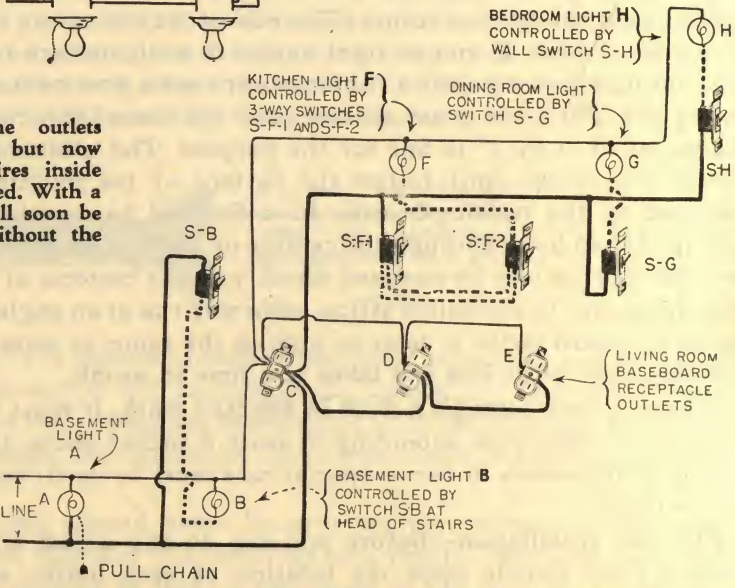


Fig. 8-7. The same outlets shown in Fig. 8-6, but now showing how the wires inside the cable are connected. With a little practice, you will soon be able to get along without the plans.

After you have decided which outlets are to go on each circuit, draw a diagram of each circuit; show how the cable is to run from one outlet to the next, from outlet to switches, and so on. A typical diagram of this kind is shown in Fig. 8-6 which shows 8 outlets, plus 3 single-pole switches and a pair of 3-way switches. The outlets have been labeled A, B, C, D, E, F, G.

and H. Switches have all been labeled S, that controlling outlet B being indicated as S-B, that controlling outlet G as S-G, that for outlet H as S-H, and the two 3-way switches controlling outlet F as S-F-1 and S-F-2.

This diagram still does not tell us how to connect up the wires inside the cable, so that all the parts will work properly. Draw a second diagram and forget that *cable* is being used; show the wires separately just as if they were open wires. Fig. 8-7 shows the same outlets as Fig. 8-6, and each outlet has been labeled the same as in Fig. 8-6. Note that the same scheme has been used as in Chapter 2: a light line like this ——— for a white wire, a heavy line like this ——— for a black wire (or other color, but not white), and a heavy broken line like this — — — for the black wire (or other color, but not white) between a switch and the outlet it controls.

In the diagram of Fig. 8-7 you will see that outlet A, if you disregard the cable that runs on to B, is the same as the outlet shown in Fig. 5-3 in Chapter 5, and no detailed explanation is necessary. However, Fig. 8-8 shows the appearance of this outlet completely installed with an outlet box.

To better understand the wiring of each additional outlet, consider the cable that runs to it *from the previous outlet,* as the SOURCE for the new outlet. For example, the cable that runs from outlet A to outlet B becomes the SOURCE for outlet B.

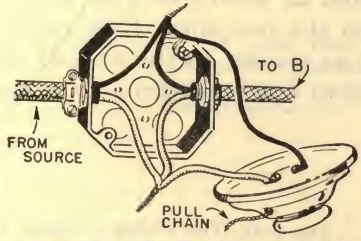


Fig. 8-8. Outlet A of Figs. 8-6 and 8-7, completely installed. The wiring is the same as was shown in Fig. 5-3.

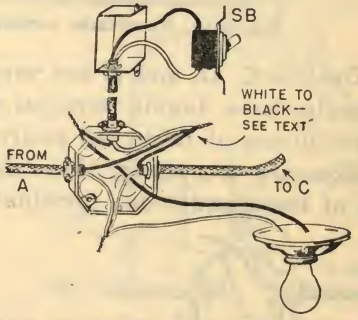


Fig. 8-9. Outlet B—an important diagram. It shows how to connect the white wire in the cable which runs to a switch.

Outlet B, if you will disregard the cable running on to C, is the same as that in Fig. 5-5 in Chapter 5, so a detailed explanation may seem entirely unnecessary. However, according to everything you have learned up to this point, and as shown in Figure 8-7, *both* wires from outlet B to switch S-B should be *black,* and the 2-wire cable that you are going to use for the purpose contains one black and one white wire. How then can you comply with the Code? The Code in Sec. 2006b makes an exception to the general rule; when wiring with cable (whether non-metallic or armored) it permits a white wire to be used where a black wire should be used—but *only* in the cable running from an outlet to a switch. It is easy to make the right

connections if you will remember that each fixture *must* have one white and one black wire connected to it, and if you observe the following simple steps:

1. At the switch, connect the two wires of the cable to the switch.
2. At the outlet, connect the white wire from SOURCE to the fixture, as usual.
3. At the outlet, connect the *black* wire from SOURCE, to the *white* wire of the cable that runs to switch; this is contrary to the general rule, but permitted by the Code's exception. This is the only case where a white wire may be connected to a black wire.
4. Connect the black wire of the cable that runs to the switch, to the fixture as usual.
5. The two wires running on to the next outlet are connected to the two incoming wires (from SOURCE) in the outlet box—black to black, and white to white.

When outlet B is properly installed according to these simple rules, it will be connected as shown in Fig. 8-9.

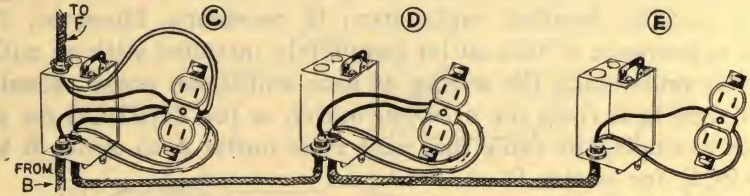


Fig. 8-10. Receptacle outlets are easy to wire as this picture shows.

Outlets C, D, and E are very simply wired as shown in Fig. 8-10. Receptacles have double terminal screws so that the two wires from two different pieces of cable can easily be attached as shown. In the case of C, it is necessary to connect three different wires to the receptacle, so connect two of them under one terminal screw.

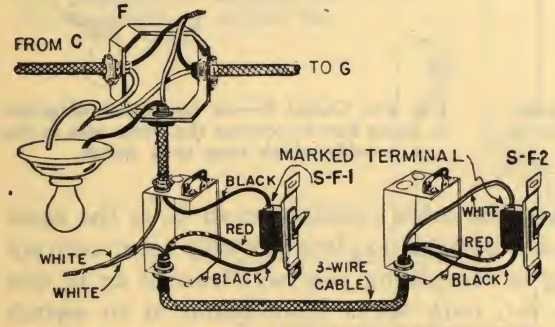


Fig. 8-11. The wiring of outlet F of Figs. 8-6 and 8-7 is shown here, with the switches that control the outlet. This is the diagram for any outlet controlled by 3-way switches, when using cable. Study carefully the colors of the wires in the cable. Compare it with Fig. 5-14.

Outlet F in Fig. 8-7, if you disregard the cable running on to the next outlet G, is the same as Fig. 5-14 in Chapter 5. Run a length of 2-wire cable from the outlet to the first 3-way switch S-F-1, and a length of 3-wire cable from there to the second 3-way switch S-F-2. Again we meet the problem of the proper colors of wire. Remembering the steps outlined in connection with outlet B, simply connect the white wire from SOURCE (which in this

case is the white wire from outlet C) to the fixture as usual. The other wire on the fixture *must* be black, so connect the black wire of the cable that runs on to the first switch S-F-1. At the outlet, the white wire in the cable that runs on to the switch, is connected to the incoming black wire from SOURCE, contrary to general rule but permitted by Code exception. The cable that runs on to the next outlet G must also be connected; black wire to black and white to white, of the cable from SOURCE (from C). This completes the wiring of the outlet F, leaving the switches still to be connected.

Two different pieces of cable end in the box for S-F-1: one 2-wire cable, one 3-wire cable, five wires altogether. Two of them are white; splice them together so that there will then be a continuous white wire from F to S-F-1 to S-F-2, where it is connected to the common or marked terminal of that switch. The black wire in the cable between F and S-F-1 is attached to the common or marked terminal of the first switch S-F-1. That leaves two unused wires in the cable from S-F-1 and S-F-2: the red and the black. Connect them to the remaining terminals of each switch; it does not matter which color goes to which terminal on the switch. This finishes the wiring which is shown in Fig. 8-11.

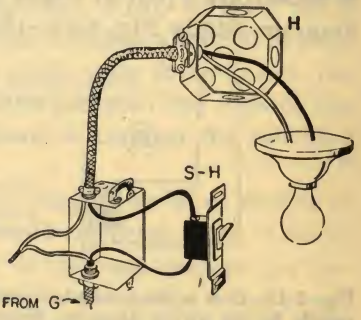


Fig. 8-12. Sometimes the cable from SOURCE does not run first to the outlet, then to the switch. Here is shown the wiring when it runs first to the switch, then to the outlet.

Outlet G you will see is exactly the same as outlet B; wire it in the same way.

Feed Through Switch Box—In all the outlets wired so far, the cable ran first to the outlet box and fixture, then on to the switch. When you come to outlet H of Fig. 8-7, you will see that the cable runs first to the switch box S-H and then on to outlet H. This combination is even simpler to wire than the others, for there is no problem with the colors of the wire, as you can see from Fig. 8-12, which pictures this outlet completely wired.

Outlets Beyond H—Additional outlets can *not* be installed beyond H by simply attaching the black and white wires of the cable for the new outlet, to the black and white wires in outlet H, because then the new outlet would be turned on and off by switch S-H.

An additional outlet can be added by tapping in at the switch S-H; splice the wires of the cable for the new outlet, to the incoming cable from G,

as shown in Fig. 8-13. Another way is to run 3-wire cable from S-H to H; splice the two wires in the cable for the new outlet, to black and white in H, as shown in Fig. 8-14.

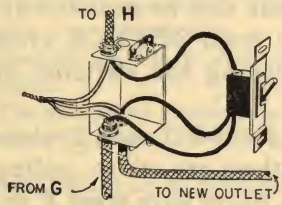


Fig. 8-13. One method of adding an outlet beyond an existing outlet.

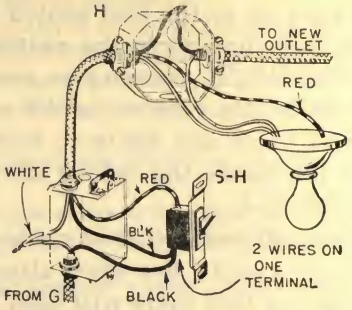


Fig. 8-14. Another method of adding an outlet beyond an existing outlet.

A cable to any additional outlet can be spliced to any existing cable in any outlet box by splicing white to white, black to black, *if each wire can be traced all the way back to SOURCE without interruption by a switch.*

Substituting 3-Way Switches for Single Pole—It is a very simple matter to substitute a pair of 3-way switches for a single-pole switch, in any wiring diagram. Study Fig. 8-15—the starting point is an outlet already wired with

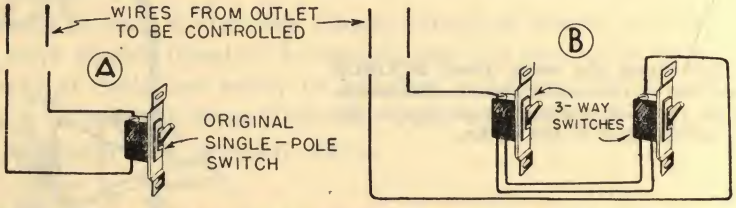


Fig. 8-15. It is a most simple matter to substitute a pair of 3-way switches for a single-pole switch, in any wiring diagram. Simply substitute the right-hand combination for that shown on the left.

two wires ready for a switch. If a single-pole switch is to be used, connect it to the two ends of the wires as at A. If a pair of 3-way switches is to be used, substitute the combination of B.

If you want to add a switch to a diagram which shows an outlet permanently connected, without a switch, cut the black wire. That gives you two ends of black wire to which the switch connects, or two ends to which you will attach the 2-wire cable which runs to the switch.

Junction Boxes—Sometimes it is necessary to make a T connection in cable, when there is a long run and no convenient outlet from which to start the T branch. In that case, use an outlet box, run the three (or more) ends of cable into it, splice all black wires, all white; cover with a blank cover, and the job is finished. See Fig. 8-16. Such junction boxes must always be located *where permanently accessible.*

Completing the Wiring—Since at the moment we are studying the wiring of a building while it is being built, we can't at this stage finish the wiring by installing switches, receptacles, wall plates and fixtures. This work is done later after the plastering and similar work is done, and how to do it will be covered in a later chapter.

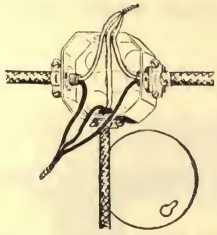


Fig. 8-16. A box used to splice several pieces of cable.

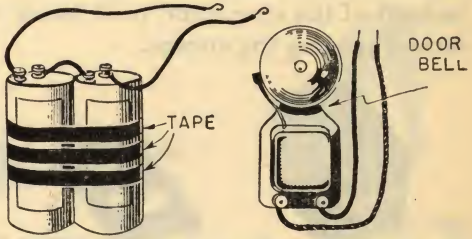


Fig. 8-17. To test the finished wiring, all you need is a doorbell and a couple of dry cells.

Testing Wiring—After the wiring is all installed, it must be tested. All you need for this is a doorbell and a couple of dry cells. Be sure all the wires which later are to be soldered are twisted together. Also, at each point where a switch is to be installed, have all the wires to which a switch is later to be attached, touch each other, just as if the switch were there and in the ON position. Do not, however, twist them together, for then the ends of the wires will no longer be straight and it will be hard to connect the switches later.

When all this has been done, connect two dry cells in series as shown in Fig. 8-17, leaving a hook on the end of each wire. Hook these ends of wires across the wires of the cable where they attach to the fuse cabinet (or circuit breaker). You will then have 3-volt current in your line, where you later will have 115-volt current. Touch the doorbell across each pair of wires at the various outlet boxes where a fixture or a receptacle outlet is later to be connected; if the wiring has been properly done, the bell will ring. If the outlet in question is controlled by a switch, the bell should stop ringing when the two wires, where the switch is later to be connected, are separated. If everything checks out OK, the wiring is properly done and is ready for the installation of switches, receptacles and fixtures as outlined in a later chapter.

Wiring 230-volt Devices with Cable—When a motor or other device is to be operated at 230 volts, it is wired with two wires, neither of which is grounded—they are the two outside wires of the diagram of Fig. 6-1. Because neither wire is grounded, neither one may be white. But every 2-wire cable contains one white wire, so paint the insulation on the ends of the white wire black; the cable then is considered as consisting of two black wires.

Cable with Ground Wire— In a very few localities a special type of non-metallic cable is required. This cable, in addition to the usual wires, contains another grounding wire which is bare, uninsulated. For example, 14-2 cable of this type has two insulated wires plus one bare wire. If this cable is required in your locality, use it in the usual way but attach the bare ground wire solidly to each outlet and switch box. It may be clamped under the locknut of the connector, or if boxes with clamps are used, under one of the screws holding the clamps.

Fig. 8-18. In some localities, boxes made of insulating material (bakelite, porcelain) are used instead of metal boxes. No connectors are required on the boxes, but the cable must be supported within 6 inches of every box.

Non-Metallic Outlet Boxes—Under today's Code, outlet and switch boxes made of bakelite or porcelain are *permitted* with non-metallic cable; some future Code will probably *require* them in place of steel boxes when non-metallic cable is used.

Two boxes of this kind are shown in Fig. 8-18 together with one of the covers for use with them. Use such boxes in the same way as steel boxes, except that it is not necessary to use connectors or clamps with them, if the cable is anchored within 6 inches of the box.

Fig. 8-19. Each of these devices is a combination outlet box and switch (or similar device) and cover, very handy and practical especially in wiring barns, garages, basements, attics or similar locations where the wiring is exposed.

In place of the bakelite boxes with covers, a special line of surface wiring fittings shown in Fig. 8-19 may be used. Each device consists of box and cover and device (switch or receptacle or outlet) all complete. These devices are very handy and popular in barn wiring, and other locations where the wiring is exposed. Each device comes in two pieces: base and cover. Locate them where they are not easily damaged.

CHAPTER 9

Wiring with Armored Cable

Armored cable is quite simple in construction as Fig. 9-1 shows. The wires are the ordinary rubber-covered type; they are wrapped in a spiral layer of tough kraft paper. The galvanized steel armor is strong and tough but quite flexible.

Fig. 9-1. Armored cable consists of two or more rubber-covered wires, protected by a layer of tough paper and a flexible, galvanized steel armor.

Fig. 9-2. Support cable with staples.

This material may be used only in permanently dry locations, so can't be used outdoors. (A special type is available which has lead-covered cable inside the armor and that may be used anywhere.) Like non-metallic cable, it must be supported every 4½ feet and also within 12 inches of every outlet or switch box. It may be fastened with straps similar to those used with non-metallic cable, but staples shown in Fig. 9-2 are more frequently used; simply drive them home with a hammer. The armor of the cable prevents damage. Sharp bends in cable must be avoided; the Code says that the bends must be such that, if completed into the form of a complete circle, the circle would be at least 10 times the diameter of the cable.

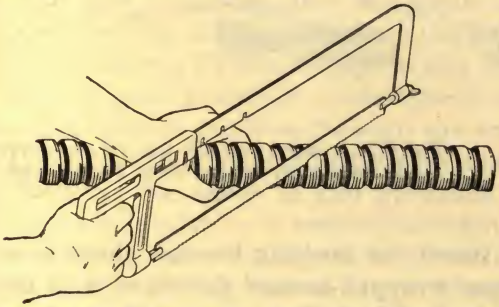


Fig. 9-3. Note the proper angle of the blade in sawing the armor of cable. Be careful not to damage the wires.

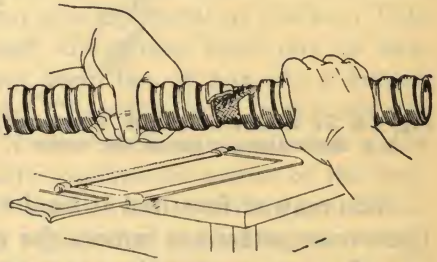


Fig. 9-4. A twist will remove the cut end of the armor. Let about 8 inches of wire stick out beyond the armor.

Cutting Cable—Use a hacksaw and hold it in the position shown in Fig. 9-3. Note that the blade must be almost at right angles to the strip of armor, rather than to the cable itself. Be very careful so that the saw goes only through the armor and does not touch the insulation of the wires. This

is not too easy and if you have not had experience, make some practice cuts on odd pieces of cable before proceeding to do wiring. Usually bending the cable at the point where it is to be cut is helpful in sawing. Actually it is difficult to saw completely through only a single strip of armor, but usually if the center part of the strip is sawed completely through and the edges partly through, a sharp bend will break the armor. A sharp twist on the two pieces of armor as shown in Fig. 9-4 will remove the short end. The cut should be made about 8 inches from the end of the piece, so that there will be plenty of wire in the outlet box when it is installed.

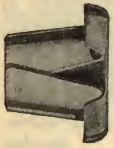


Fig. 9-5. The fiber anti-short bushing shown at the left must always be used at the cut end of cable, between the wires and the armor. It provides protection against sharp edges of armor, which might puncture a wire and cause a short-circuit.

Bushings—After you have cut a length of cable, examine the cut end of the armor and you will see that there are sharp jagged edges on the armor, pointing inward toward the wire. These teeth sometimes puncture the insulation of the wire and cause short circuits and grounds. For this reason the Code requires that a bushing of tough fiber must be inserted at the end of the cable, between the steel armor and the wires. Such bushings are supplied with the cable and Fig. 9-5 shows one of them.

Fig. 9-6. To remove the paper, first unwrap it a short distance inside the armor.

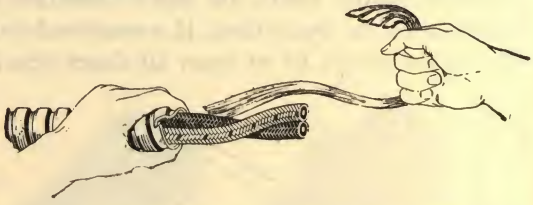


Fig. 9-7. A sharp pull will tear off the paper *inside* the armor, making room for the bushing.

You may at first find it hard to insert the bushing because there is so little room under the armor; the paper wrapped around the wires is in the way. So, you must make room for the bushing—first unwrap the paper a few turns *under* the armor, then give it a sharp yank and it will tear off *under* the armor, all as shown in Figs. 9-6 and 9-7. The bushing is then inserted as shown in Fig. 9-8. Fig. 9-9 shows a cross-section of a piece or cable with the bushing properly inserted.

Connectors—Immediately after inserting the bushing, install a connector on the cable as was shown in Chapter 7 in the steps of Figs. 7-8 and 7-9, (unless you are using boxes with cable clamps, which make the use of con-

nectors unnecessary). The connectors used with armored cable are almost the same as those used with non-metallic sheathed cable except that they must be what is known as the visible type. At the end which goes inside the box, there are "peep-holes" through which the red color of the bushing can be seen; this allows the inspector to see that the bushings have been used. If you do not use the bushings, your job will not be passed by the inspector.

Fig. 9-8. Inserting the bushing between the armor and the wires of the cable.

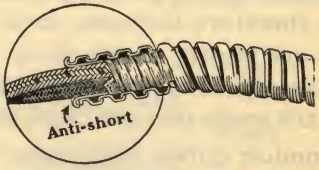


Fig. 9-9. A properly-installed bushing in place.

Using the Cable—After the cut ends have been prepared with the bushings and connectors, install the cable in the same way as described for non-metallic sheathed cable in the previous chapter. The problems of the correct colors of wire are exactly the same as with non-metallic sheathed cable.

As with non-metallic cable, splices are not permitted; the cable must be in one piece from box to box. If a splice is necessary, make it in a junction box as shown in Fig. 8-16.

Be specially careful in attaching the connectors to outlet and switch boxes. The connector must be tightly clamped to the armor of the cable; after inserting the connector into the knockout of the box, the locknut must be driven down tightly enough to bite down into the metal of the box. This makes a good electrical connection through the armor from box to box, so that current can flow through the armor from box to box. As a matter of fact, this sometimes actually does happen. The white wire in the cable is grounded; the armor is also grounded. If the black wire at some point where the insulation is removed accidentally touches the armor or the box, it is the same as touching the white wire. That is a short circuit and causes the fuse protecting that circuit to blow, a signal that something is wrong.

Testing—Make the same tests as with non-metallic sheathed cable. Then make one more test: at each outlet connect the doorbell between the black wire and the box itself. If black enameled boxes are used, scrape a little of the enamel off the box at the point where you touch the wire from the bell to it. The bell should ring, because touching the bell to the box is the same as touching it to the white wire, for both are grounded. It will not ring as loudly as when touched to both wires, but it should still ring. If it does not, go around and tighten up locknuts on the connectors.

CHAPTER 10

Wiring with Conduit

There are two different types of conduit. The original type is known as rigid conduit; the newer type is known as thin-wall conduit or Electrical Metallic Tubing (EMT). The rigid type will be described first and later in the chapter the thin-wall type will also be discussed.

Dimensions—Conduit, size for size, has the same dimensions as water pipe, therefore the same tools are used for cutting or threading. Standard sizes are known as ½, ¾, 1, 1¼, 1½, and 2 inches. Still larger sizes are used mostly in commercial work. The actual inside diameter is a little larger than the trade size indicated above.

Conduit differs from water pipe in several ways. It is much softer so that it bends easily; it is carefully inspected to make sure that it is entirely smooth inside to prevent damage to the wires as they are pulled into the

Fig. 10-1. Rigid conduit looks like water pipe but differs in several important respects. It comes only in 10-foot lengths and each length bears the Underwriters' label.

pipe; it has a rust-resistant finish both inside and out. The finish may be either black enamel or galvanized. The galvanized is considered the better and has gradually become the commonly used type. The black may be used only indoors. Each length bears an Underwriters' label.

Bending Conduit—If conduit is bent sharply, it will collapse; it must be bent in such a way that the internal diameter is not reduced at the bend. The Code says that the bend must be gentle and gradual, so that if continued into the form of a complete circle, the circle would be at least 12 times the inside diameter of the conduit. If lead cable is to be pulled into the conduit, the diameter of the circle must be at least 20 times the inside diameter of the conduit. Special bending tools are available which make bending easy, but for occasional jobs special tools are not necessary. Bend the conduit around any solid round object such as a post, a keg, or similar object. Factory-bent elbows are also available.

Cutting Conduit—Cut conduit with a hacksaw. This usually leaves a sharp edge at the cut which might damage the insulation of the wires as they are pulled into the conduit. The Code requires that the inside of each cut end must be reamed to remove these sharp edges. Thread with the same tools used for water pipe.

Installing Locknut and Bushing—Conduit is attached to an outlet box by means of a locknut and bushing, both of which are shown in Fig. 10-2. Their use is made clear from Fig. 10-3 which shows how the locknut is used on the outside of the box, the bushing on the inside. The locknut is not flat, but has teeth on one side; the side with the teeth faces the box. The bushing has a rounded surface on the inside over which the wires slide while being pulled into the pipe. To install properly, first screw the locknut on the pipe as far as it will go, then slide the pipe through the knockout

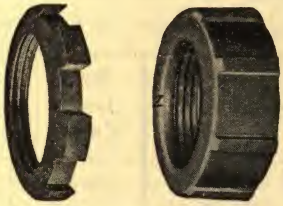


Fig. 10-2. Conduit is attached to boxes by means of locknuts and bushings, both shown above.

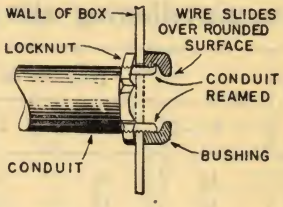


Fig. 10-3. This shows how a locknut and bushing is used. Be sure the locknut is driven home solidly.

in the box, then install the bushing on the inside of the box. Screw the bushing on tight, as far as it will go, and only then tighten up the locknut on the outside of the box, running it home tight so that the teeth will dig down into the metal of the box.

Thin-Wall Conduit—This material is properly known as Electrical Metallic Tubing, or EMT. It is shown in Fig. 10-4 and, as in the case of

Fig. 10-4. Thin-wall conduit cannot be threaded; it is much lighter than rigid conduit. It comes only in 10-foot lengths and each length bears the Underwriters' label.

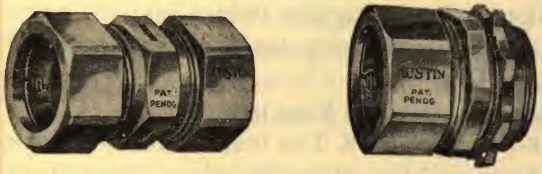


Fig. 10-5. Thin-wall conduit is attached to boxes with the connector shown at left. The picture also shows a coupling.

the rigid, each length bears an Underwriters' label. It comes only in a galvanized finish. It may be used either indoors or outdoors. Size for size, it has the same inside diameter as rigid conduit, but the outside diameter is much less than that of rigid conduit. This is because the wall is much thinner; as a matter of fact, the wall is so thin that it cannot be threaded.

Lengths are coupled together and connected to boxes with special pressure fittings—coupling and connector are both shown in Fig. 10-5. Tightening the nut securely clamps the conduit into the fitting.

Cutting and Bending Thin-Wall Conduit—A hacksaw is the most convenient tool for cutting this material. It must be reamed after cutting. Bend it like rigid conduit.

Size Conduit to Use—Whether thin-wall or rigid conduit is used, the Code restricts the number of wires of any given size that may be used inside each size of conduit. The size pipe required for each combination is shown in the following table:

Size of Wire	Number of Wires to be Installed						Size Lead Cable	Size Conduit, In.
	1	2	3	4	5	6		
14	½	½	½	½	¾	¾	14-2	¾
12	½	½	½	¾	¾	1	12-2	¾
10	½	¾	¾	¾	1	1	10-2	¾
8	½	¾	¾	1	1¼	1¼	8-2	1
6	½	1	1	1¼	1½	1½	14-3	¾
4	½	1¼	*1¼	1½	1½	2	12-3	1
2	¾	1¼	1¼	2	2	2	10-3	1
0	1	1½	2	2	2½	2½	8-3	1

* Where a service run of conduit or electrical metallic tubing does not exceed 50 ft. in length and does not contain more than the equivalent of two quarter bends from end to end, two No. 4 insulated and one No. 4 bare conductors may be installed in 1-in. conduit or tubing.

Installing Conduit—Whether rigid or thin-wall conduit is used, the procedure is the same. The pipe is first installed, the wires pulled into it later. No run (as the distance from box to box is called) may have more than the equivalent of four quarter-bends in it. All wires must be continuous, no splices being permitted inside the pipe. The conduit is supported by means of pipe straps; it should be anchored every 6 to 10 feet.

The conduit must be cut to the proper length and then bent to suit the purpose. It is best not to mount the boxes too rigidly before installing the conduit, for the finished piece with bends may turn out to be a fraction of an inch too long or too short.

Pulling Wires Into Conduit—Assume that you have installed the conduit for outlets A, B, C, and D of Fig. 8-7 in Chapter 8. The installation will look as shown in Fig. 10-6. You are ready to pull the wires into place. For a short run with just two small wires, they can probably be simply pushed in at one end and through to the next outlet. If the runs are longer, and especially if there are bends, this cannot be so simply done and fish wire must be used. Special fish wire may be purchased; it consists merely of a steel tape about ⅛-inch wide and about $\frac{1}{16}$-inch thick. It is flexible enough to go around

corners and springy enough so it will not buckle when pushed into the conduit.

In pulling the wires into the outlets of Fig. 10-6, you have a choice of pulling in short pieces from SOURCE to A, two more pieces from A to B, two more from B to C, and still two more from C to D, or you may pull two continuous wires from SOURCE to A to B to C to D. The latter is the simpler plan, so simply push the fish wire in at D to C to B to A until it emerges at SOURCE. Attach the two wires to the fish wire at SOURCE, then pull on the fish wire at D. Have another man at SOURCE help the wires on their way and to keep them from snarling. In this way, a continuous

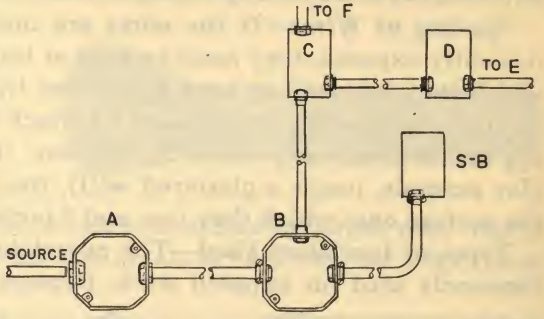


Fig. 10-6. Outlets A, B, C, and D of Figs. 8-6 and 8-7, installed with runs of conduit, ready for the wires to be pulled in.

pair of wires will be pulled in from SOURCE all the way to D, at which point about eight inches are left sticking out. Holding tight at D, pull wires out at C until there is a loop about 6 to 8 inches long sticking out of the box at that point, in the meantime feeding in at SOURCE. This loop when cut in the middle (or in some cases merely having the insulation removed at the middle) is the same as the two ends of wire in the case of cable sticking out of the same box. Repeat at B and A, in the meantime feeding in at SOURCE. Two additional wires must be pulled in from B to S-B. This completes the installation of the wires in these four boxes and the procedure from this point onward is the same as with cable—merely installing switches, receptacles, fixtures, and so on.

Be sure to use black wire and white wire as required; there are no exceptions as when using cable. Use white wire only from SOURCE to each outlet, never to a switch. The other wires may not be white. Use black, or black and red to make it easy to trace wires when there are several inside one pipe.

Hangers—When using hangers of the type described in connection with Fig. 7-16, be sure to use the deep type, otherwise there will not be room for the conduit and locknut behind the plaster. Use a plaster ring on top of each box, as described in connection with Fig. 7-19. If the wiring is exposed, either a deep or a shallow hanger may be used.

Testing—Test in exactly the same way as armored cable.

CHAPTER 11

Wiring with Knob-and-Tube System

The knob-and-tube system was used in the first wiring jobs about 60 years ago. It is still in common use in some parts of the country; in other parts it is completely unknown. It consists of rubber-covered wires mounted on porcelain insulators, with additional forms of protection where required. So far as the Code is concerned, it may be used anywhere. It is not, however, accepted by REA for outbuildings. This system uses a little less material than other systems, but requires more labor. The wires, being more or less exposed, are more readily damaged than those in other systems.

Spacing of Wires—If the wires are installed so that they will be permanently exposed, they must be kept at least ½ inch from the surface over which they run, and at least 2½ inches from each other. If used in a wet location, the spacing is increased to 1 inch from the surface, with the same 2½ inches from each other. If, however, the wires will later be concealed (for example, inside a plastered wall), then they must be kept 1 inch from the surface over which they run, and 3 inches from each other.

Types of Insulators Used—The porcelain cleat illustrated in Fig. 11-1 is commonly used for exposed work. Because these cleats separate the wires only 2½ inches, they may not be used for concealed work. Most of the cleats on the market do not come equipped with nails, but some merchants do carry them in stock with nails which have leather washers, which makes it much easier to install them. The leather washers keep the porcelain from breaking when the nails are driven in.

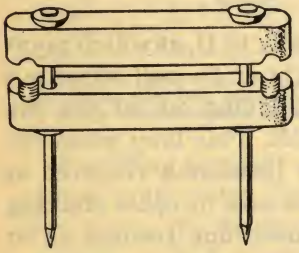


Fig. 11-1. Porcelain cleats shown here may be used only with wiring that is permanently exposed.

Fig. 11-2. Use knobs for concealed or exposed work.

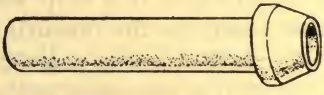


Fig. 11-3. Use a porcelain tube at each point where wire runs through timber; run each wire through a separate tube.

The porcelain knob shown in Fig. 11-2 may be used for either concealed or open wires. Only one wire may be installed on each insulator. The knob comes in two pieces, each piece having a groove to hold the wire. The wire is installed between the two parts. These knobs are also equipped with nails and leather washers.

Wherever a wire must pass through a timber, as for example a joist or stud, it must be protected by a porcelain tube which is shown in Fig. 11-3. These tubes come in assorted lengths as required. The tubes are also used for other purposes, as will be explained later.

Loom—There are many cases where it is impossible to keep the wires separated from the surface or from each other by the required distance. In that case the Code requires that *each* wire be enclosed *in a separate piece* of loom, which material is shown in Fig. 11-4. Loom is a flexible woven fabric tube which is finished in moisture- and fire-resisting materials, also having good insulating qualities. Loom comes in several diameters, the smallest of

Fig. 11-4. Use loom over each wire when it is impossible to maintain the separation required by Code. Never run two or more wires through one piece of loom.

which is known as 7/32 inch, but is actually considerably larger than that in inside diameter. It is big enough for No. 14, 12, or 10 wire. The larger sizes are for larger sizes of wire.

Outlet Boxes—With knob-and-tube wiring that is permanently exposed, outlet boxes are not required by the present Code. The fittings in Figs. 11-5, 11-6, 11-7, and 11-8 are permitted instead. The devices shown in Fig. 11-5

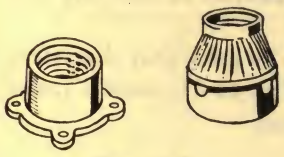


Fig. 11-5.

Fig. 11-6.

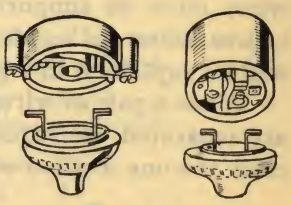


Fig. 11-7.

The devices shown above may be used only with wiring that is permanently exposed. It is much better to use outlet boxes which make a safer job.

are known as cleat receptacles, accommodating lamp bulbs. The device shown in Fig. 11-6 is a brass shell socket with a porcelain base, and is more convenient than the cleat receptacle mentioned because it has a pull-chain for controlling the light. The devices shown in Fig. 11-7 are known as rosettes, and are used for drop cords. The drop cord is attached to the bottom half of the device, and the house wiring to the upper half. A twist solidly connects the two parts but allows separation when required. Fig. 11-8 shows a surface style switch.

Although the present Code permits these devices for *exposed* wiring, it is quite likely that some future Code will outlaw them and require outlet boxes

for every point where current is taken from the wires or where a switch is used. Even if outlet boxes are not required now, it is very wise to use them. Their use makes a much sturdier, safer, and in general more satisfactory installation.

If the wiring is concealed, a box is required at every outlet or switch. A box is not required where wires are tapped to each other.

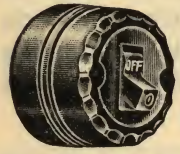


Fig. 11-8. A surface switch. Switch mounted on outlet box cover is better.

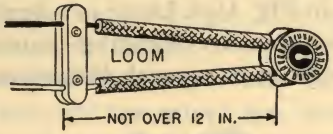


Fig. 11-9.

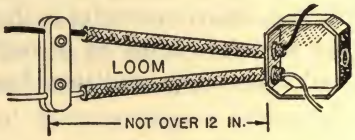


Fig. 11-10.

When wires come closer together than required by Code, slip loom over each wire. Support the wires within 12 inches of every box or device.

Where wires are attached to a surface wiring device or where they enter a switch or outlet box, they automatically come closer together than permitted by Code. This makes it necessary to use a piece of loom over each wire at each device or box. The Code also says that the wires must be anchored within 12 inches of every box or device. See Figs. 11-9 and 11-10, which should make the required construction clear.

Details of Installation—Whether the wiring is concealed or open, the wires must be supported on insulators at least once every 4½ feet. Of course, when *old* buildings are wired this requirement cannot be met but that will be explained in a later chapter on "old work."

When a pair of wires must make a right angle turn, be sure that the wires are separated the required distance at the corners. Fig. 11-11 should make clear the one method which answers Code requirements.

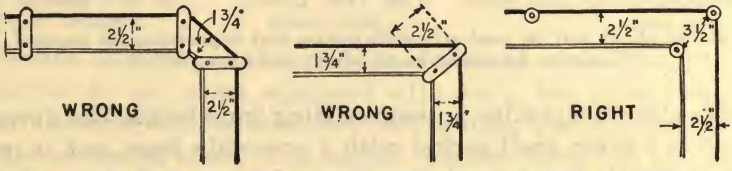


Fig. 11-11. Make sure wires are properly separated at corners.

When installing porcelain tubes through bored holes in timbers, be sure the holes are bored at a slight angle. Unless this is done, especially if the holes are a bit over-size, the tubes will tend to fall out of their holes with the vibration of the building. At any point where a wire runs off at right angles along the timber, after having come through a tube in the timber, mount a knob close to the tube. Both of these points are shown in Fig. 11-12.

When a wire runs up and down inside a wall and through a floor, it is not enough to insert a porcelain tube through the floor timbers. It is necessary to drop another tube on top of the one that goes through the timber, to insulate the wires from loose plaster, dust, shavings, and other things which might drop down inside the wall. This is shown in Fig. 11-13.

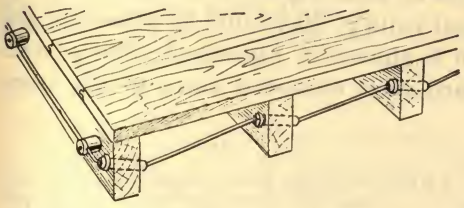


Fig. 11-12. Bore the holes for porcelain tubes at a slight angle, so that the tubes cannot fall out of them.

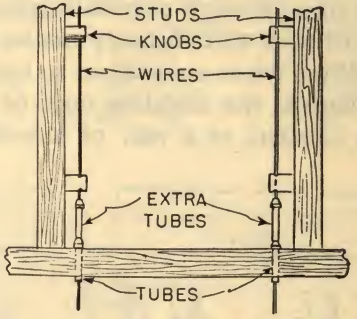


Fig. 11-13. Use extra tubes where wires go through floor timbers inside a wall.

Wires must be kept at least 2 inches from all metal work such as water pipes, gas pipes, metal ducts for hot-air heating systems, etc. If this is not possible, cover each wire with a separate length of loom. Be sure it is fastened well so that it cannot slip out of place.

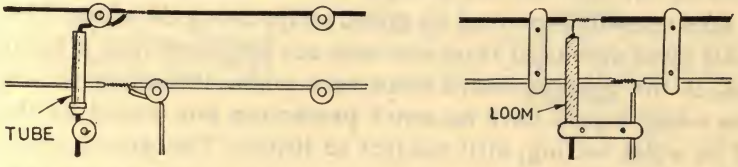


Fig. 11-14. Use a piece of loom or a porcelain tube, when wires cross each other. Wires must be supported within 6 inches of every tap. Solder and tape every joint.

Taps—When it is necessary to tap wires, an outlet box is not required. However, the wires must be anchored within six inches of the tap and, since one of the wires must cross another, they will of course come closer together than is permitted. This in turn requires extra insulation which may be either a porcelain tube or a piece of loom. In any case the loom or the porcelain tube must be long enough so that it cannot possibly slip out of place. This construction is shown in Fig. 11-14.

This picture shows an apparent violation of the rule that only one wire may be mounted on one knob. However, since the one wire is tapped to the other wire that runs through the knob, the two may be considered one wire.

Wires Subject to Mechanical Injury—Such wires must be given special protection. It is difficult to define just when a wire is subject to mechanical injury and when it is not. Good judgment must be used, and the local electrical inspector is the final judge. However, the Code does say that any exposed wire within seven feet of the floor is considered subject to mechanical injury, if it runs on top of or across timbers such as studs or joists. If it runs through porcelain tubes or parallel with the timber and along the side of it, it will probably not be considered as being subject to such injury.

When wires are subject to mechanical injury, they must be given special protection, the simplest form of which is shown in Fig. 11-15. The protection consists of a pair of wooden guard rails mounted close to the insu-

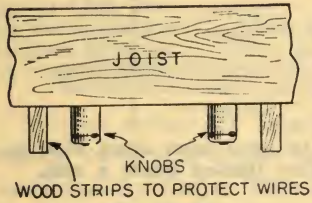


Fig. 11-15.

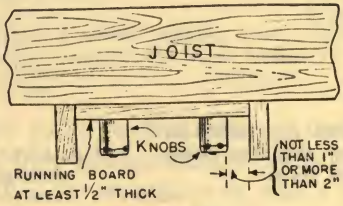


Fig. 11-16.

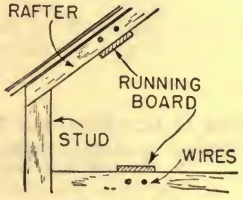


Fig. 11-17.

Several methods of protecting wires which are exposed to mechanical injury.

lators, at least as high as the insulators, and at least 7/8-inch thick. Another method is shown in Fig. 11-16 where a running-board at least 1/2-inch thick is mounted on the timbers; the wires are then mounted on top. The running-board in turn must be protected by guard strips along the sides. The running-board itself must extend at least one inch but not more than 2 inches beyond the wires. If the running-board were very wide, extending far beyond the wires, the wires would have no extra protection but would be the same as mounted on a flat ceiling, still subject to injury. The guard strips must be at least 2 inches high.

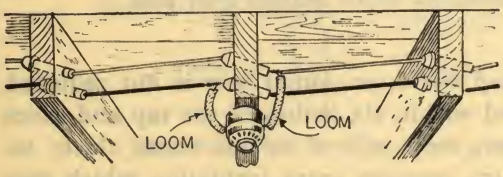


Fig. 11-18. The simplest method of installing an outlet in exposed work. Solder and tape all joints. Using an outlet box would make a much better installation.

In unfinished attics which are accessible, protect the wires as shown in Figs. 11-15 or 11-16. Moreover, if they run through bored holes in floor joists or studs or rafters, within 7 feet of the floor, they would not ordinarily have to be protected but, in the case of attics, must have a running-board mounted above them so as to afford protection. This is shown in Fig. 11-17.

Actual Installation, Exposed Wires—The details in general have already been covered, but a few illustrations should be helpful. Fig. 11-18 shows a typical installation of an outlet, but it would be far better to use an outlet box as shown in Fig. 11-19. If the wires are run parallel with the timber, mount as shown in Fig. 11-20, following the details of construction there shown.

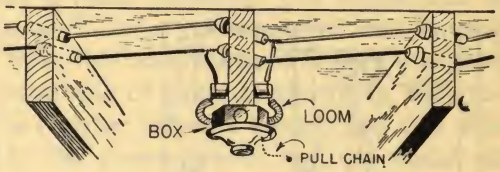


Fig. 11-19. The same outlet shown in Fig. 11-18, but here installed with an outlet box. It makes a sturdier and safer installation.

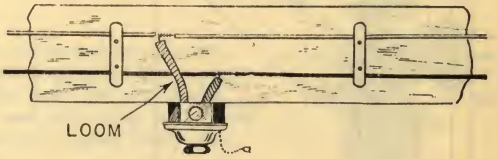


Fig. 11-20. The same outlet shown in Fig. 11-19, but here the wires run parallel with the timber instead of running at right angles.

Actual Installation, Concealed Wires—The outlet of Fig. 8-8, which we installed with cable in Chapter 8, is shown installed with knob-and-tube wiring in Fig. 11-21. If this same outlet were permanently exposed, porcelain cleats could be used instead of the knobs shown.

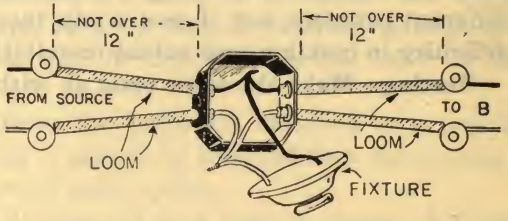


Fig. 11-21. The outlet shown installed with cable in Fig. 8-8, is here shown wired with the knob-and-tube system.

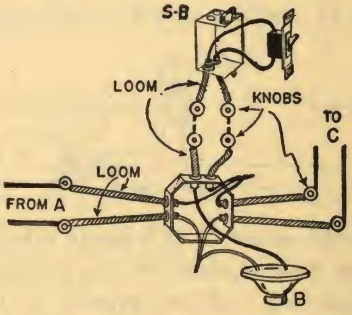


Fig. 11-22. The outlet shown installed with cable in Fig. 8-9, is shown here wired with the knob-and-tube system. There is no problem in connection with the colors of wire, as in the case of cable wiring.

Fig. 11-22 shows the outlet of Fig. 8-9, which we wired with cable in Chapter 8. You will see that there is little difference except in the method

of mounting each wire singly on insulators instead of having both of them inside cable.

Fig. 11-23 shows how the outlet shown in Fig. 11-22 might look installed in a wall. The actual location of the box for the fixture and the box for the switch would vary a great deal with the particular circumstances, but the drawing shows the general method of construction.

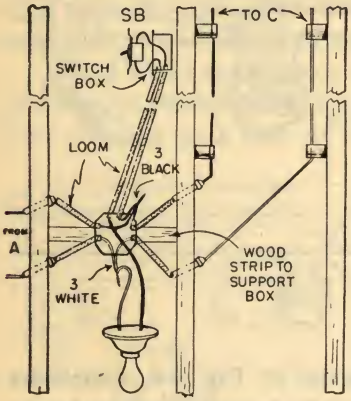


Fig. 11-23. Actual installation of the outlet shown in Fig. 11-22. Of course each installation would differ in many mechanical respects from the one shown here, as to exact location of the boxes, number of knobs used, exact direction wires will run, and so on.

A good deal of cleverness will have to be used in the exact method of running wires inside walls, to keep them separated the required distance from each other, still using a minimum of loom. Each installation is a different problem, but if you study this chapter well, you will have little difficulty in making your actual installations.

Testing—Make the same tests as with non-metallic sheathed cable.

CHAPTER 12

Miscellaneous Wiring

In any wiring job there are a number of miscellaneous problems which do not properly fall into any previous chapter. These things will be discussed in some detail here.

Radio Outlets—Every house has a radio problem. The aerial and the ground wires frequently come in jammed under the window itself, through holes bored in walls, and so on. At best, the usual method is very unsightly. Special radio outlets are available and one of these is shown in Fig. 12-1. The device has connections for the regular 115-volt outlet, and two more connections for aerial and ground; the power wires, and the aerial and

Fig. 12-1. The radio outlet shown at the right has two outlets, separated from each other. The aerial and ground of the radio are attached to the special plug which fits only the top outlet. The bottom outlet is a 115-volt outlet and any plug will fit. Note the steel barrier which separates the two outlets inside the box.

ground wires, are carefully separated from each other in the box by a metal divider so that there is no possible chance for a short circuit between them. Install this outlet as you would any other outlet, and run two additional wires to it, one to the radio ground and the other to the aerial. The aerial itself may be the usual outdoor type with the lead-in running through the wall up to the outlet, or an aerial may be concealed in the attic of the building, as you see fit.

The aerial and ground wires from the radio are attached to a special plug; its blades are so designed that it cannot be inserted into the ordinary power outlet, but only into the special radio outlet.

Doorbells and Buzzers—These devices are very easy to install. A transformer is used, which is a device which reduces the 115-volt current to a

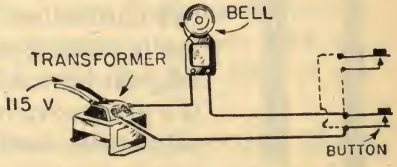


Fig. 12-2. The wiring of a doorbell with a transformer is most simple, as this diagram shows.

much lower voltage; for doorbell use this is usually about 8 to 12 volts. Most transformers have two "primary" wire leads coming out of them, which are connected to the 115-volt wires. The current is always on, but doorbell transformers are so made that they consume practically no power, less than

1 watt, except when the bell is ringing, when they draw about 5 watts from the line. Transformers operate only on Alternating Current.

The installation is very simple. Consider the two "secondary" or low-voltage terminals on the transformer as the SOURCE for a circuit, the bell as the outlet, and the button as a switch. Breaking it down this way makes all these diagrams very simple. Fig. 12-2 shows the installation of one bell with a button in one location. If a button is wanted in an additional location, install it as shown in the dotted line, in parallel with the first button.

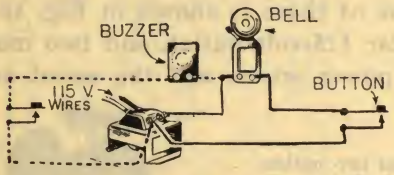


Fig. 12-3. This shows a bell for the front door, a buzzer for the back door, both operated by the same transformer.

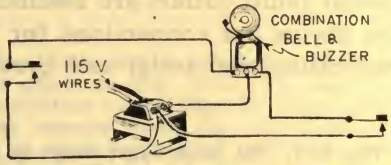


Fig. 12-4. This shows a combination bell-buzzer, serving the same purpose as a separate bell and separate buzzer.

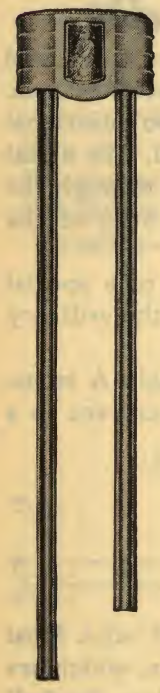


Fig. 12-5. Musical chimes are fast replacing doorbells.

In most installations, a single bell is not considered enough. The usual system is to install a bell for the front door, a buzzer for the back door. See Fig. 12-3, and you will see that it is the same as Fig. 12-2 for a single bell, with the buzzer added as shown in the dotted lines. Also common is the combination bell-and-buzzer shown in Fig. 12-4. You must connect the wire which runs from the transformer directly to the device to the correct terminal on the combination bell-buzzer. This is not always the middle terminal as shown in the diagram. The correct terminal is the one that is not insulated from the case or base of the device by insulating washers, like the others are.

Instead of doorbells, musical chimes are becoming very common. One of them is shown in Fig. 12-5. The better ones are so arranged that when the front door button is pushed, two musical notes are sounded, and when the back door button is pushed, only a single note is sounded. No matter how long the button is held down, the sound does not repeat. This is a great advantage over the harshness of the ordinary doorbell which usually rings much longer than is necessary. It is just a question of time before the ordinary doorbell will be practically unknown. The wiring of these devices is the same as the doorbell. The better chimes on the market today operate on the same transformer as used for ordinary doorbells; formerly special transformers delivering about 20 volts were required.

Because the usual transformer used for doorbells and chimes cannot deliver a great deal more than 10 volts, nor more than about 5 watts, there is no danger of shock or of fire. Therefore the wire used for this low-voltage wiring does not need much insulation, and bell wire of the kind shown in Fig. 12-6 is commonly used; it is insulated only with a couple of layers of paraffined cotton. Staple it to the surface over which it runs.

Fig. 12-6. Bell wire has little insulation because of the low voltage and limited power involved.

Garage Wiring—The outlets in a garage should be fed by underground wires because overhead wires are often in the way. For underground use, the lead-sheathed cable pictured in Fig. 12-7 may be used. It must be run inside conduit because the lead sheath is merely protection against moisture;

Fig. 12-7. The lead sheath of this cable keeps moisture out, but lead is soft and therefore not very strong mechanically. For this reason lead-sheathed cable must be protected by conduit.

Fig. 12-8. Underwriters' Type USE cable has no lead sheath but the outer layer is exceedingly tough. Bury it directly in the ground.

it is too weak for mechanical protection. It is better to use a new type of material shown in Fig. 12-8, which has a special type of insulation that is very moisture-resisting, plus an outer tough, Neoprene armor layer—far stronger and more durable than lead or natural rubber. It is buried directly in the ground without further protection. Bury as many single conductors as required. This material is approved by the Underwriters as style USE entrance cable and may be used for underground work per Sec. 3035 of the Code.

Fig. 12-9 shows typical construction using lead cable and conduit. Make the bends gradual so that the lead cable can be pulled into the conduit easily without damage to the lead. Fig. 12-10 shows the wiring diagram which you will recognize as the ordinary, every-day diagram for using 3-way switches.

If you want the garage to have a receptacle outlet which is always on (instead of being turned off and on with the garage light) it will be neces-

sary to add a fourth wire as shown in the dotted lines in Fig. 12-11. This receptacle outlet will be very handy to operate a battery charger, a trouble-light, or other things of that nature. Four* wires are required, and cable with four wires is hard to find. Use overhead wires, or separate single-conductor wires shown in Fig. 12-8, or two 2-wire cables.

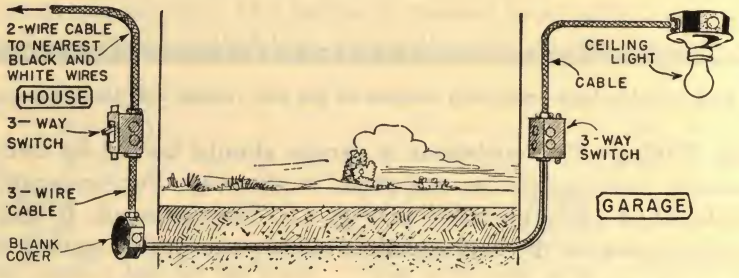


Fig. 12-9. A typical installation of garage wiring, using lead-sheathed cable inside conduit.

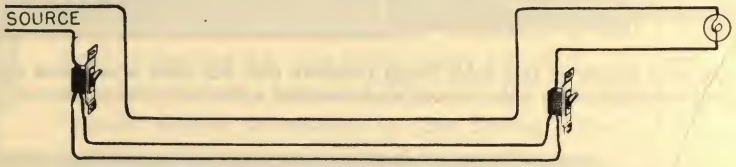


Fig. 12-10. Wiring diagram of the installation in Fig. 12-9.

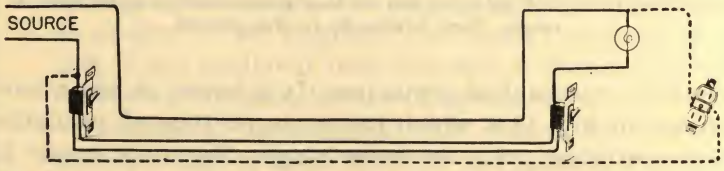


Fig. 12-11. If a receptacle outlet in the garage is to be always on, even after the light has been turned off from the house, four wires are necessary.

If overhead wires are used, there are several different ways in which the wires may be brought into the garage and out of the house. Fig. 12-12 shows a style of entrance cap which is most convenient, requiring only a single hole through the wall, and no special assembling. Its use is shown in the same picture. Fig. 12-13 shows another way using the ordinary entrance cap as used for service entrances, a short piece of conduit, and an outlet box inside of the building. Fig. 12-14 shows the right way using knob-and-tube system.

* There is a "trick" circuit which requires only three wires, but it is not safe and does not meet Code requirements.

Drop Cords—Drop cords are very simply assembled as Fig. 12-15 shows. The Code requires that an Underwriters' knot be tied into the cord at top and bottom, as shown in the same picture. This puts the weight of the assembly on the complete wire, including the insulation; if the cord is not knotted, the weight is entirely on the copper conductors of the wire, which are not nearly as strong as the complete wire. This is an important detail which should not be overlooked.

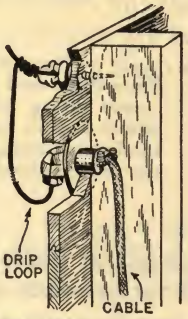


Fig. 12-12.

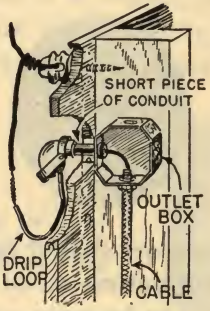


Fig. 12-13.

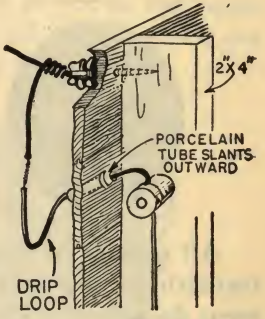


Fig. 12-14.

Three different ways of bringing wires into a garage or other building. The method shown in Fig. 12-12 is the simplest and easiest to use.

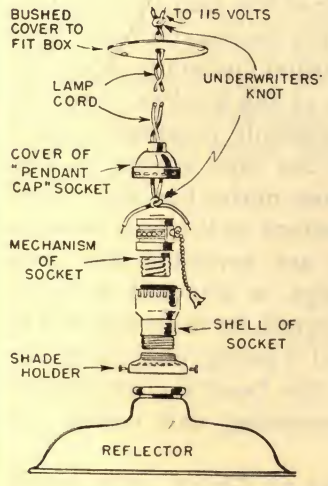
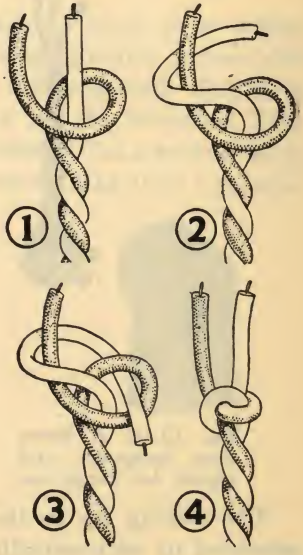


Fig. 12-15. In making a drop cord, always use an Underwriters' knot at each end. This takes the weight off the copper conductors of the lamp cord. The knot is easily made as shown at the right.



Basement Wiring—If the basement is well finished, with plastered ceilings, the wiring is no different from that of any other part of the house. There are, however, so many different kinds of construction in a basement that different types of wiring must be used, depending entirely on the particular circumstances involved.

If the cable is to run on the surface of the wall, the outlet and switch boxes will be mounted on the surface also. In that case, use "handy boxes," described in connection with Fig. 7-5. The use of these boxes has the advantage that there are no sharp edges or corners exposed.

Also quite commonly used are receptacles and switches mounted on covers to fit on top of ordinary octagonal outlet boxes, either 3¼ or 4 inch size. These devices are shown in Figs. 12-16 and 12-17.

Fig. 12-16 and Fig. 12-17. Receptacles and Switches mounted on round covers fitting on ordinary boxes are commonly used in basements, barns, garages, and similar locations. All-bakelite insulating covers are considered safer than metal covers.

All sockets in basements should be made of porcelain, bakelite, or other insulating material, but not metal. Ordinarily, when you stand on the basement floor, you are apt to be more or less in contact with moist earth, the ideal conditions for a shock. Use sockets and other devices made of insulating materials—Safety First.

Fig. 12-18. A heavy duty receptacle and pigtail for range use.

Electric Ranges—Electric ranges at maximum heat operate on 230 volts; at low heat they operate on 115 volts. Therefore it is necessary to run three wires to the range. The usual method is to install, in a convenient location in the kitchen, a special heavy-duty 50-ampere 250-volt receptacle. Such receptacles are usually the type shown in Fig. 12-18, being a combination outlet box and receptacle mounted on the surface of the wall or baseboard (similar outlets are available for flush mounting). To the range is attached a heavy flexible 3-wire cord or pigtail, on the other end of which is found a special 3-prong plug to fit the receptacle. The use of this flexible cord permits the range to be disconnected and moved for cleaning.

The wiring up to the range outlet may consist of 3-wire cable, either armored or non-metallic. Usually however service entrance cable is used, the same material used in bringing the wires into the building, and as shown in Fig. 6-8. The bare wire of the cable may be connected only to the neutral wire. The electric range is the only device inside a building which may be connected with service entrance cable. Size 8-3 cable is sometimes used, but size 6-3 is more common.

Electric Hot Water Heaters—These heaters are very simply installed, always operate on 230 volts, and 2-wire cable is used. It is necessary to paint the ends of the white wire black because neither wire is grounded. The wire required is usually a No. 10 but is sometimes heavier, depending on the size of the heater. The Code says that this heater must be wired so that it can be disconnected by a switch, for which purpose an ordinary switch costing only a couple of dollars is usually used—see Fig. 12-19. An unfused switch is suitable, but there is no objection to one of the fused type. Usually unfused switches are hard to find, while all dealers stock the fused type. Be sure the switch has two blades and two fuses.

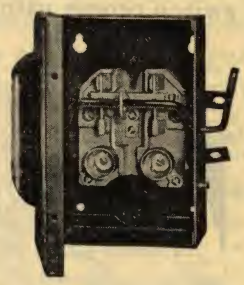


Fig. 12-19. A switch of this type is used for water heaters, motors and similar devices. Use a switch with one fuse for 115 volts, a switch with two fuses for 230 volts.

Motor Driven Appliances—Any motor-driven device such as a water pump or an oil burner, must be controlled by a separate switch, unless the motor has a cord and plug so that it can be easily disconnected. This is a safety measure; turn off the switch when working on the machine. The same type of switch shown in Fig. 12-19 above is suitable. Use a switch with one fuse if the motor operates on 115 volts, with two fuses if it operates on 230 volts.

CHAPTER 13

Finishing an Installation

All the work described up to this point is done as the building progresses; the finishing touches such as the installation of the switches, the receptacles, wall plates and fixtures, take place only after the house is plastered, papered, and painted. This portion of the work is only a very small part of the total and is very easy.

Installing Wiring Devices—Fig. 13-1 shows how to mount switch and its plate on a switch box. The switch is attached to the switch box using machine screws that come with the switch. The plate in turn is installed on the switch proper using screws that come with the plate.

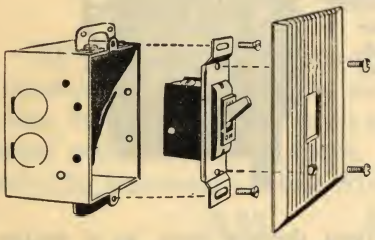


Fig. 13-1. The switch or other device is first mounted on the box, the plate then fastened to the device.

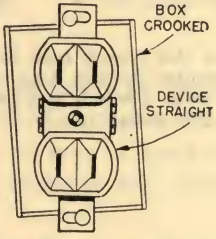


Fig. 13-2. Devices can be mounted straight on a crooked box because of oval holes in strap.

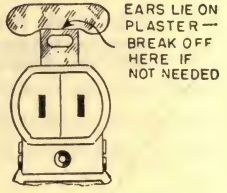


Fig. 13-3. Plaster ears are helpful in aligning a device flush with the plaster.

Inspect any switch or receptacle or similar device; you will see that the holes for the screws which hold the device to the box are not round but oval. These openings are oval so that the device can be mounted straight up and down in the wall even if the box is not mounted straight up and down. See Fig. 13-2, which shows a box mounted crookedly. The picture should make clear how the device can be straight in spite of the crooked box.

The switch box should be mounted so that its front edge is flush with the plaster. This is not always done and often you find boxes which are somewhat below the surface of the plaster. If the device is mounted flush with the box, it will be too deep inside the wall so that it will not stick far enough through the openings in the switch plate, when it is finally put on. This not only makes an untidy job but also makes it hard to operate switches. For this reason spacing washers are usually supplied with switches and similar devices; these washers are placed between the device and the switch box, to raise the device up so that the plate will fit properly. On some devices "plaster ears" are found (See Fig. 13-3), which will lie on top of the plaster and bring the device to the proper level, even if the box is somewhat below

the surface of the plaster. Plaster ears are usualy found only on the more expensive devices. The ears can be broken off easily, if for any reason they are in the way.

Mounting Wall Plates—When mounting wall plates, do not draw up too tightly on the mounting screws. The most common plates are made of bakelite, and are fairly easily damaged. On plates for duplex receptacles there is a very narrow strip of material between the two openings and, if you pull down too tightly on the screw, you will crack this bridge and ruin the plate.

Hanging Your Fixtures—On some fixtures you will find that one wire is white, and the other is black. More usually they are both the same color, but one has a colored tracer thread woven into the cotton covering of the wire. The white wire, or the wire with the tracer, always goes to the white wire in the box. The other wire goes either to the black wire in the box, or to the switch.

The wires from the fixture may be soldered to the wires in the box in accordance with soldering instructions in Chapter 3. Each joint must be covered with rubber tape and then with friction tape. Solderless connectors may be used instead; their use was also covered in the same chapter.

The Code says that all fixtures must be mounted on outlet boxes; they may not be mounted directly on your ceiling. The very simplest fixtures can be mounted directly on outlet boxes using screws supplied with the fixture. This method is shown in Fig. 13-4. Somewhat larger fixtures often use a special strap supplied with the fixture, and this method should be clear from Fig. 13-5 and 13-6.

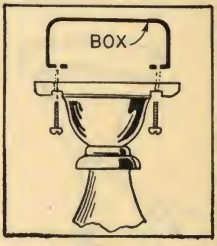


Fig. 13-4. Simple fixtures can be mounted directly on the outlet box. The fixture becomes the cover of the box. Be sure the outlet box is rigidly mounted, to support the weight of the fixture.

Still larger fixtures are commonly hung directly on a fixture stud mounted in the bottom of your outlet box, or the fixture stud which is part of the hanger on which your box is supported. The "stem" of the fixture is threaded to fit the fixture stud. The canopy is made to slide down the stem; when the work at the outlet box is finished, all connections made, slide the canopy up to conceal the wiring. Fig. 13-7 shows this common method; see also Fig. 7-18.

In old houses, fixtures sometimes must be supported on the end of existing gas piping. Cap the gas pipe with a "blind hickey" shown in Fig.

13-8. There is an obstruction in one end of this device, which caps off the gas. The wires from the fixture come out through the open sides of it.

Wall brackets are mounted in various ways, depending on the particular kind of outlet box used. In new work today, switch boxes instead of outlet boxes are usually used for wall brackets, because wall brackets are frequently of rather dainty shape and size, which will cover a switch box, but would not cover the larger outlet box. Usually a strap is used which mounts

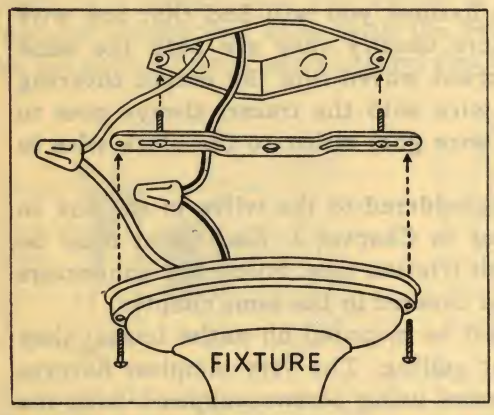


Fig. 13-5. Sometimes a strap is first mounted on the box, the fixture then mounted on the strap.

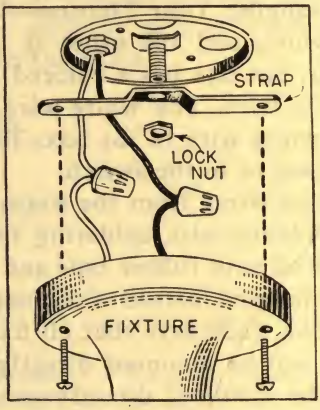


Fig. 13-6. Another method of mounting a fixture on a box, still using a strap.

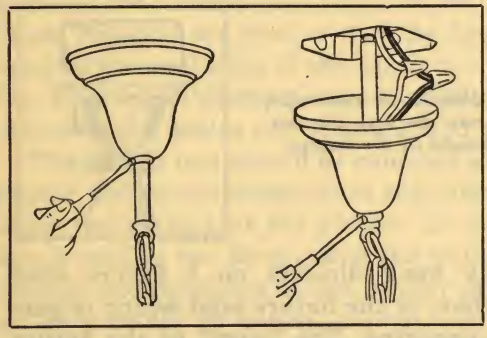


Fig. 13-7. Fixture mounted on a fixture stud in the bottom of the box. See also Fig. 7-18.

Fig. 13-8. A hickey sometimes used between the fixture and the stud. If the thread in the upper portion does not go all the way through, and there is an obstruction, it is known as a blind hickey.

directly on the switch box, the fixture then mounting on the strap. See Fig. 13-9. Regardless of the type of box used, if a fixture stud is present, use a brass adapter which rigidly supports the bracket. See Fig. 13-10.

An outdoor porch fixture is easily installed. If it is on the ceiling of a porch, or on the side of the house but protected by the porch roof, wire it in the same way as indoors. If it is exposed to the rain, wire as in indoor work but make sure the fixture has a porcelain socket, and rewire it with No. 14 rubber-covered wire in place of the No. 18 fixture wire usually used.

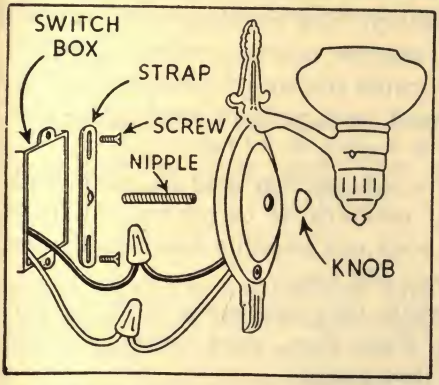


Fig. 13-9. Wall brackets are usually mounted on switch boxes, using a strap.

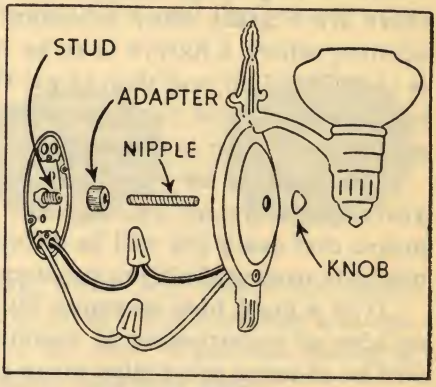


Fig. 13-10. Another method of mounting a wall bracket, using a fixture stud.

It is impossible to cover all possible methods of mounting a fixture; it all depends on the size and construction of your particular fixture. With the help of the general information given here you should have no trouble, for fittings to suit the particular fixture involved are usually supplied by the manufacturer.

CHAPTER 14

Old-Work Installations

Everything in previous chapters describes "new work," or the wiring of buildings while they are being built. This chapter will describe the wiring of buildings after they have been completed; this is known as "old work." There is very little difference between the two, except that in old work there are a great many problems of carpentry. The problem is to cut an opening where a fixture is to be installed, another opening where a switch is to be installed, and then to get the cable inside the wall from one opening to the other—with the least amount of work, and without tearing up the plaster more than is necessary.

One house to be wired may be five years old, another may be a hundred years old; different builders use different methods of carpentry. All this means that every job will be different. No book can possible describe all the methods used and all the problems that you will meet.

It is a good idea to watch buildings while they are being built, to get an idea of construction at various points. Even then, good common sense will be of more value than many pages of instruction.

In general, old work requires more material because it is often wise to use ten extra feet of cable to avoid cutting extra openings in the plastered walls, or to avoid cutting timbers. In locating outlets, bear in mind that all wires must be fished through walls and ceilings. Sometimes by moving an outlet or a switch a foot or so, a difficult job of boring through joists or other timbers can be avoided. Most problems can be solved without cutting any openings except the ones which are to be used for outlet boxes and switch boxes. Others require that temporary openings be cut in the wall, which must later be repaired.

Systems Used for Old Work—The conduit system cannot be used for old work unless the building is being practically rebuilt. Occasionally the knob-and-tube system is used, but since the wires cannot be anchored as required for new work, the Code requires that *each* wire be enclosed in a *separate* length of loom extending from one outlet box to the next. Because two lengths of wire and two separate lengths of loom cost more than a single length of cable, and require much more work for installation, the knob-and-tube system is little used for old work.

For old work, cable is used almost entirely, either armored or non-metallic, as is the custom locally. On farms, use non-metallic cable.

Code Requirements for Old Work—For new work, the Code requires boxes at least 1½ inches deep. For old work, it permits boxes as shallow as ½ inch, but only when use of the deeper boxes would injure the structure of the building. Fig. 14-1 shows a number of such shallow boxes.

Since it is impossible to do so, the Code does not require that cable be anchored every 4½ feet, like in new work. The cable is simply pulled into the walls and anchored only to the outlet and switch boxes. Each piece must be a continuous single length from box to box.

Temporary Openings—Sometimes a temporary opening must be made in a wall, so that cable can be fished around a corner. On papered walls, use a sharp safety-razor blade, cut through the two sides and the bottom of a square. Soak the cut portion with a wet rag, which will soften the paste. Lift the cut part off the wall, bend it upwards, using the top edge as a hinge. Use a thumb-tack to hold it in place, out of the way. When the wiring is finished and the plaster replaced, paste the paper back into place.

Fig. 14-1. Boxes less than 1½ inches deep are permitted for old work, if using 1½-inch-deep boxes would injure the structure of the building.

Preparing Openings—On all openings the plaster must come up close to the box. It is impossible to cut an opening of the exact size of the box, so in most cases it will be necessary, after the wiring is finished, to replace the plaster so that it will come up close to the box. Use a simple mixture of plaster of paris, or prepared patching plaster.

In most cases the switch and outlet boxes are supported directly or indirectly by the lath under the plaster, so choose the locations for the openings carefully. A location fairly close to joists and studs is best because there the laths are strongest. On the other hand, if located too close to a stud or joist, there may not be enough room to bring the cable freely into the box without awkward bends and extra work.

Make a mark on the wall or ceiling approximately where you want the box to be. Bore a small hole through this mark. Probe with a stiff wire to make sure there is no obstruction and if you find sufficient free space on both sides, mark the full size of the opening. Don't make your opening too snug. Allow about ⅛ inch extra so that you can slide the box easily into the opening. With a keyhole saw, enlarge the bored hole sufficiently so that a hacksaw blade may be inserted. Insert this blade in such a way that the actual sawing is done as you pull the blade out of the wall toward yourself. If this is not done, if you saw as you push the blade into the wall, there is considerable danger of loosening the laths from the plaster as you push in, making a very flimsy mounting for the box. Hold your hand against the plaster as you pull out. Saw the opening to the required size and shape.

Mounting of Switch Boxes—In sawing the openings for switch boxes, remember that the length of a switch box is approximately the same as two widths of lath, plus the space between the laths. If you remove two complete widths of lath, the mounting brackets on the switch boxes will just barely reach the next two laths. As a result the wood screws by which you attach the boxes (one-inch No. 5 screws are commonly used) will come very close to the edges of the laths, and the laths will split, making a very loose mounting and an unsatisfactory job. Remove one width of lath completely,

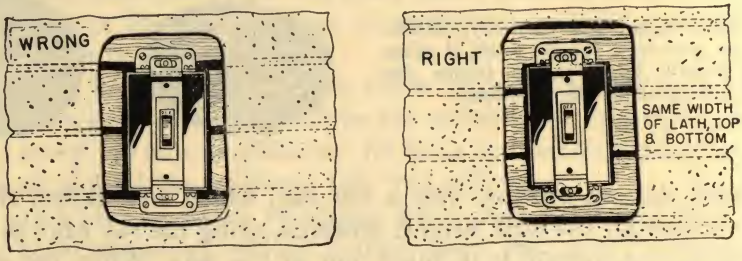


Fig. 14-2. In cutting an opening for a switch box, cut away one whole lath, and part of another lath on each side of the one completely cut. This provides a rigid mounting for the box.

and part of another on *each* side of the opening. Fig. 14-2 shows the wrong and the right way, and should be self-explanatory.

Whether connectors are used or whether the box has clamps for holding the cable, the cable is attached to the box while it is still outside the wall. Therefore it is best to run the cable into the box through knockouts in the bottom, rather than the ends or sides of the box. This makes it much easier to insert the box into its opening in the wall.

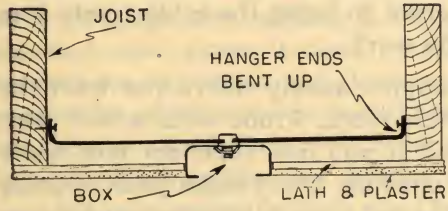


Fig. 14-3. Method of supporting a box when there is no floor above the box, or the floor can be lifted.

Anchoring Outlet Boxes—Boxes which are 1½ inches deep should be used at all times if possible; use the shallower kind only when it is impossible to use the deeper ones.

If there is accessible space above the ceiling on which the box is to be mounted, and if there is no floor above (or if a board in the floor can be easily lifted as will be explained later), a box is mounted using a straight bar hanger of the type that was shown in Fig. 7-17 Bend the ends at right angles so that

the straight portion is just long enough to fit between two joists, and mount as shown in Fig. 14-3.

If it is impossible to work from above, and all the work must be done from below, the easiest way to mount a shallow box on the ceiling is by using an old-work hanger, shown at A in Fig. 14-4. In consists of a straight bar of metal and a sliding fixture stud mounted upon it, but not removable.

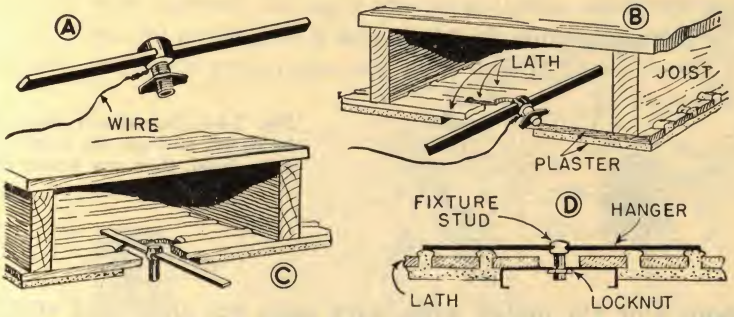
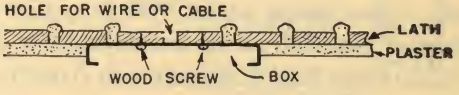


Fig. 14-4. Method of supporting a box when the floor above cannot be lifted. The old work hanger shown is very convenient for the purpose.

A small piece of wire is usually attached which avoids losing the hanger inside the ceiling.

Cut an opening into the ceiling, large enough so that the hanger can be slipped through it and for the cable to come through. Remove the plaster over a space large enough so that the outlet box can be firmly mounted flush on the lath. Slip the hanger into the opening as shown in B. Pull on the wire which is attached to the hanger until only the stud hangs down through the opening. Turn the hanger so that the bar lies at right angles to the lath. Remove the center knockout in the bottom of the box and slip it over the hanger, fasten the locknut on the stud inside the box, and the mounting is

Fig. 14-5. In some localities mounting a box directly on lath is permitted.



complete. In the meantime, of course, you will have attached the cable to a knockout in the bottom of the box by means of a connector or clamps.

Occasionally it will be acceptable to mount the outlet box directly on lath, as shown in Fig. 14-5. This method should be used only with the very lightest fixtures because the entire weight of the fixture and the box is supported by not over two laths. Using an old-work hanger distributes the weight over at least half a dozen laths.

Lifting Floor Boards—In many types of construction a board in the upstairs floor can be lifted, to get at the ceiling space. Where the flooring is rough, as in ordinary attics, this is no problem whatever. However, if the lumber used is tongued and grooved, it is not so simply done without marring the floor. The first step is to cut the tongue off the boards—a putty knife cut off short so that the blade is only about 1½ inches long, makes an excellent chisel for the purpose. Sharpen the blade and you will have a

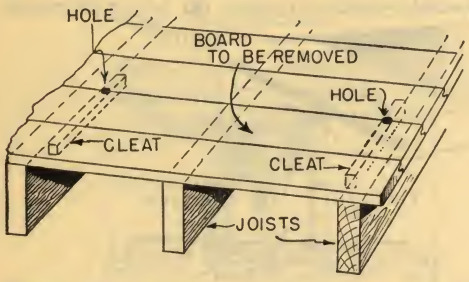


Fig. 14-6. Sometimes floor boards must be lifted. Cut off the tongue with a very thin chisel, then saw across next to joists.

chisel about 1 or 1½ inches wide, very thin, but short and stubby, which makes it strong. With this you can get down into the cracks between two boards and chisel off the tongue as far as necessary. Then bore two holes in the board as close as possible to joists—see Fig. 14-6. With a keyhole saw, cut across just as close to the joist as you can. It is best to cut at an angle so that the board, when it is replaced, more or less forms a wedge. The board should be removed over the space of at least three joists, so that the board when replaced rests firmly on at least one joist.

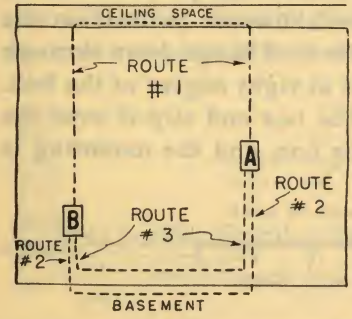


Fig. 14-7. In running cable from an opening A to another opening B, both on the same wall, there is usually a choice of three routes for the cable to follow. The best route depends on the structure of building.

When replacing the board, first nail a cleat to the joist at each point where you sawed across. These cleats must be very solidly nailed so that when the board is replaced there will be no springiness.

Problem: Two Openings on Same Wall—In Fig. 14-7 cable must run from the opening A to opening B, both in the same wall. Depending on the structure of the building, the cable may run in one of three ways. The simplest way is marked "Route 1" in Fig. 14-7. Use this route if the floor

boards can be easily lifted in the floor above, so that the cable can be dropped down from above, to the location of opening A and opening B.

If it is very difficult to get into the ceiling space from above, it may be possible to run the cable down through the basement as shown by "Route 2" in the same picture. If the wall is an outside wall, there will probably be an obstruction where the floor joins the wall. In most cases it is possible to bore upward through this at an angle from the basement. Then, push two pieces of fish wire upward through the bored holes until the ends emerge at A and B. Then, by pulling at A and B, fish the opposite ends of a piece of cable upward until the ends come out at A and B.

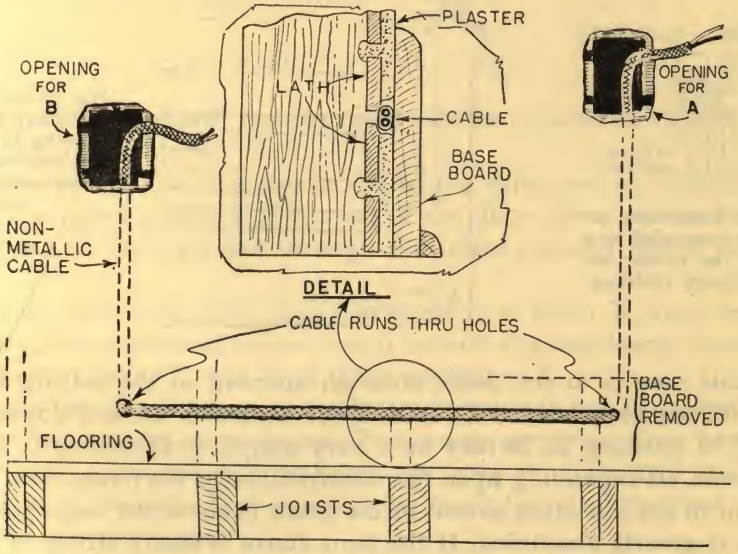


Fig. 14-8. Many times cable can be run to advantage in a trough cut in the plaster, behind the baseboard.

If the wall is an inside wall, there will probably be no partitions in the basement immediately below this wall, so that it should be possible to bore straight upward. Then fish the cable upward to opening A and opening B.

Cable Behind Baseboard—In the problem above, if it is impossible to run the cable through either the ceiling space above or the basement below, use "Route 3"—run the cable behind the baseboard along the bottom of the wall. First remove the baseboard. Then make a small opening into the wall behind the baseboard, directly under A, and another directly under B. The next step is to cut a channel between these two openings, in the space between two laths, forming a trough into which the cable can be laid. Fig. 14-8 shows the completed installation and the details of this picture should

make the method clear. Naturally, after the installation, the baseboard must be replaced. *Be extra careful not to drive the nails into the cable.*

Cable Behind Picture Molding—In older houses which still have picture molding, sometimes it is convenient to run cable behind the molding, instead of behind the baseboard. (Better consult the owner first—he may want to throw out the molding some day, which would leave a plaster-patching job to be done.) Follow the same procedure as when running the cable behind the baseboard; see Fig. 14-9.

Problem: Cable from Opening in Ceiling to Opening in Wall—Our prob-

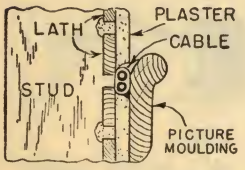


Fig. 14-9. Sometimes cable can be concealed in a trough in the plaster behind a picture molding.

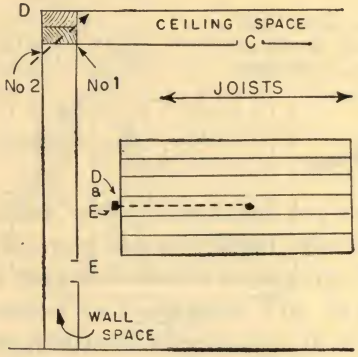


Fig. 14-10. Problem in running cable from an opening C in the ceiling, around corner at D, to opening E in the wall.

lem in this case is to run cable from an opening in the ceiling which, in Fig. 14-10, has been labeled C, around the corner at D, and down through the wall to opening E. It may be a very simple problem, or it may be a difficult one, all depending upon the construction of the house. If the ceiling joists run in the direction shown in the small inset of the same picture, the problem is greatly simplified. If the floor above is easily lifted, it is then a simple matter to pull the cable in at opening C, drop it down at D until it comes out at E. Even if there is an obstruction at D, as is usually the case, it is easy to bore a hole down from above after the board has been lifted.

If it is impossible to lift the floor above, then the cable must be gotten around the corner at D some other way. If there is a molding very close to the ceiling, remove it and make an opening into the corner at the point indicated by arrow No. 1 in Fig. 14-10. Then push a length of fish wire into this opening, jiggle it and push it and twist it until the end shows up at C. Pull it out at C until the other end is near opening No. 1. Then carefully push it downward inside the wall at point No. 1 until the end is at opening E. You then have a continuous piece from C around D to E. Attach the cable to the fish wire at C, and pull it through around D until it comes out at E.

If there is no molding, an opening must be made into the wall. Sometimes it is easier to do this on the opposite side of the wall, as at point No. 2

in the same figure. Sometimes it is necessary to bore upward through the obstructions at D, as indicated by the dotted arrow. Then by means of fish wire, it is possible to pull in the cable as before.

If the opening E is not directly below point D, as shown in Fig. 14-10, but is to either right or left, the cable can always be run over (if the floor board above can be removed) to the proper point above E and dropped down. If the flooring cannot be removed, then drop through D down to the base-

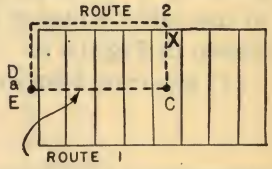


Fig. 14-11. Choice of routes for cable in Fig. 14-10, when the joists run in the direction here shown.

board; behind the baseboard run the cable over to a point below opening E, and there run upward to E.

If the joists of the ceiling run in the wrong direction, as shown in Fig. 14-11, there is again a choice of routes. If the floor above can be removed, follow "Route 1," boring holes through the joists through which the cable is to run.

If the floor cannot be lifted, make an opening at point X, drop the cable down at X to the baseboard below, run it behind the baseboard, around the corner to a point below E, and from there upward to E.

No two houses are alike, so you will simply have to use your own horse-sense in getting around obstructions. Temporary openings often have to be made, and in all cases you will probably use more material than you would for new work. A few extra feet of cable cost much less than the time it takes to follow the shortest route.

Additions to Previous Wiring—Additions to previous wiring are made just as if a complete wiring job were involved. Such small jobs usually consist of adding new outlets or switches. If you have *studied* previous chapters you should be able to make such additions without any trouble, but the following paragraphs will give you some hints for a few specific outlets. *Always turn off the main switch when working on existing wiring.*

Adding Switch to Existing Outlet—The connection in the present outlet will look a great deal like the left-hand part of Fig. 14-12. There may be more wires in the box than shown, but there will be only two wires connected to the fixture, one of them white, the other black. In the right-hand part of Fig. 14-12 is shown the same outlet after the addition of the switch. To make the proper connections at the fixture, cut the black wire, thus producing two new ends of wire. These two new ends are attached to the two wires in the cable which runs to the switch. The black wire *from the fixture* is connected

to the black wire in the new piece of cable; the black wire of the cable which runs up to the original outlet box, is connected to the *white* wire in the *new* piece of cable. This is contrary to general practice, but is the one case where the Code permits a black wire to be attached to a white, and is covered in more detail in connection with Fig. 8-9 in Chapter 8.

Often the connections are more simple, if the cable to the fixture runs up through the wall past the approximate location where the switch is to be placed. In that case, if you can get at this cable, merely cut the black wire in the cable, connect the two new ends to the switch itself, all of which is shown in Fig. 14-13.

If a pair of 3-way switches is to be added, instead of a single-pole switch,

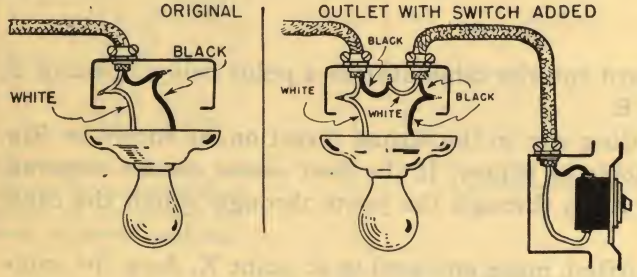


Fig. 14-12. Proper method of adding a single-pole switch to an existing outlet. If a pair of 3-way switches is to be added, see Fig. 8-15.

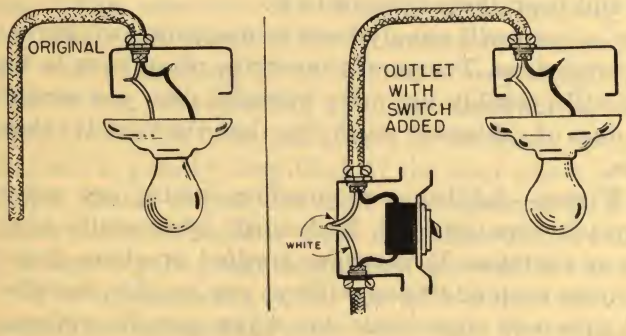


Fig. 14-13. Another method of adding a single-pole switch to an existing outlet, if the cable to the outlet happens to run past a convenient location for the switch.

proceed as outlined above except add the two 3-way switches as covered in connection with Fig. 8-15.

Adding Baseboard Outlet—This is very easily done as shown in Fig. 14-14 (for details of the mechanical installation see first part of this chapter). The end of the cable which in Fig. 14-14 is marked "To SOURCE," must be run to an existing outlet box which contains a black wire which is *always* hot, and of course must also contain the white neutral wire. If you are in doubt as to whether one of the black wires in any box is always hot, it is a simple

matter to check. Turn off the main switch. Remove the cover or the fixture from the outlet from which you plan to run. Take the tape off the connections and leave the exposed ends of wire sticking out of the box so that they are then accessible, one black wire, one white (of course carefully keeping the bare wires from touching the box). *Turn off the switch which controls*

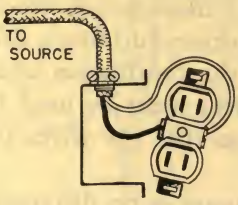


Fig. 14-14. The wiring for a new baseboard receptacle outlet is most simple.

Fig. 14-15. The wiring for a ceiling outlet is equally simple.

that outlet, and turn on the main switch. Then take a test lamp (a bulb in a socket of any type with two short wires attached to it) and touch these two wires to the wires in the outlet box. Any two wires where the bulb lights (regardless of whether the switch controlling that outlet is on or not), may be used as the SOURCE for the new run of cable. *Be sure to turn the main switch off again before working on the wires.*

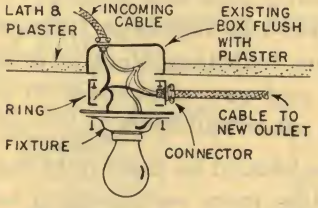


Fig. 14-16. An extension ring is often handy in basements and similar locations.

Adding New Ceiling Outlets—A new ceiling outlet may be installed as shown in Fig. 14-15, the two wires marked "To SOURCE" being run to the nearest two hot wires, as outlined in the preceding paragraph.

Extension Rings—Especially in basements, it is sometimes convenient to use an extension ring which is like an outlet box without a bottom. Remove the fixture of the existing outlet, attach the extension ring to the flush box, and wire the cable for the new run to the extension ring. Replace the fixture on top of the ring. All this should be clear from Fig. 14-16.

CHAPTER 15

Farm Wiring

When you wire a farm, you meet many new problems. The farmer uses much more power, on the average, than is used in a city home; large motors are used, perhaps a water heater for the dairy, a milk cooler, and so on. That means heavier wiring. The meter is usually installed on a pole in the yard and from there wires run to the house and other buildings. Good grounding becomes a problem because you don't have the continuous underground city water system. Between buildings, large wires must be used because of the distance, both to avoid voltage drop, and so that the wires may have sufficient mechanical strength.

Of course, the wiring inside the farm house is no different from that in houses elsewhere. The only difference there may be is in the method of grounding and that will be covered separately.

If the farm is being wired under the R.E.A. program, the outlet boxes in the barn and other outbuildings may not be of the black enamel finish, but must be galvanized or sherardized, which is very similar to galvanizing. The wiring must be done with non-metallic sheathed cable. All switches must have "T" rating.

Service Entrance—On a small farm, the entrance may be exactly as already described in a previous chapter. The meter is installed on the outside of the house, the service switch and fuse cabinet (or circuit breakers) on the inside, and a pair of wires run from the fuse cabinet to form one circuit serving the barn and other buildings. Service entrance cable may be used to run through the house and out, to connect to overhead or underground wires running on to the other buildings.

This type of service entrance should be used only for the very smallest installations. It means longer wires, more voltage drop and in general a less satisfactory installation than is obtained by locating the meter on a pole.

The usual construction at the pole is shown in Fig. 15-1. The incoming wires from the power line are anchored at the top of the pole, the neutral being the topmost wire. All three run down to the meter base which is located about 6 to 8 feet above the ground level. From the meter base, two wires run back again to the top of the pole and from there to the different buildings. Note that the neutral wire, while it runs down to the meter, does not run back to the top again, but is jumped across from the incoming power wire to the outgoing wires to the various buildings.

This makes a total of 5 wires which must run from the top of the pole to the bottom. As a 60-ampere entrance is the smallest used, this will require five No. 6 wires, and this in turn requires 1½ inch conduit. 100-ampere and

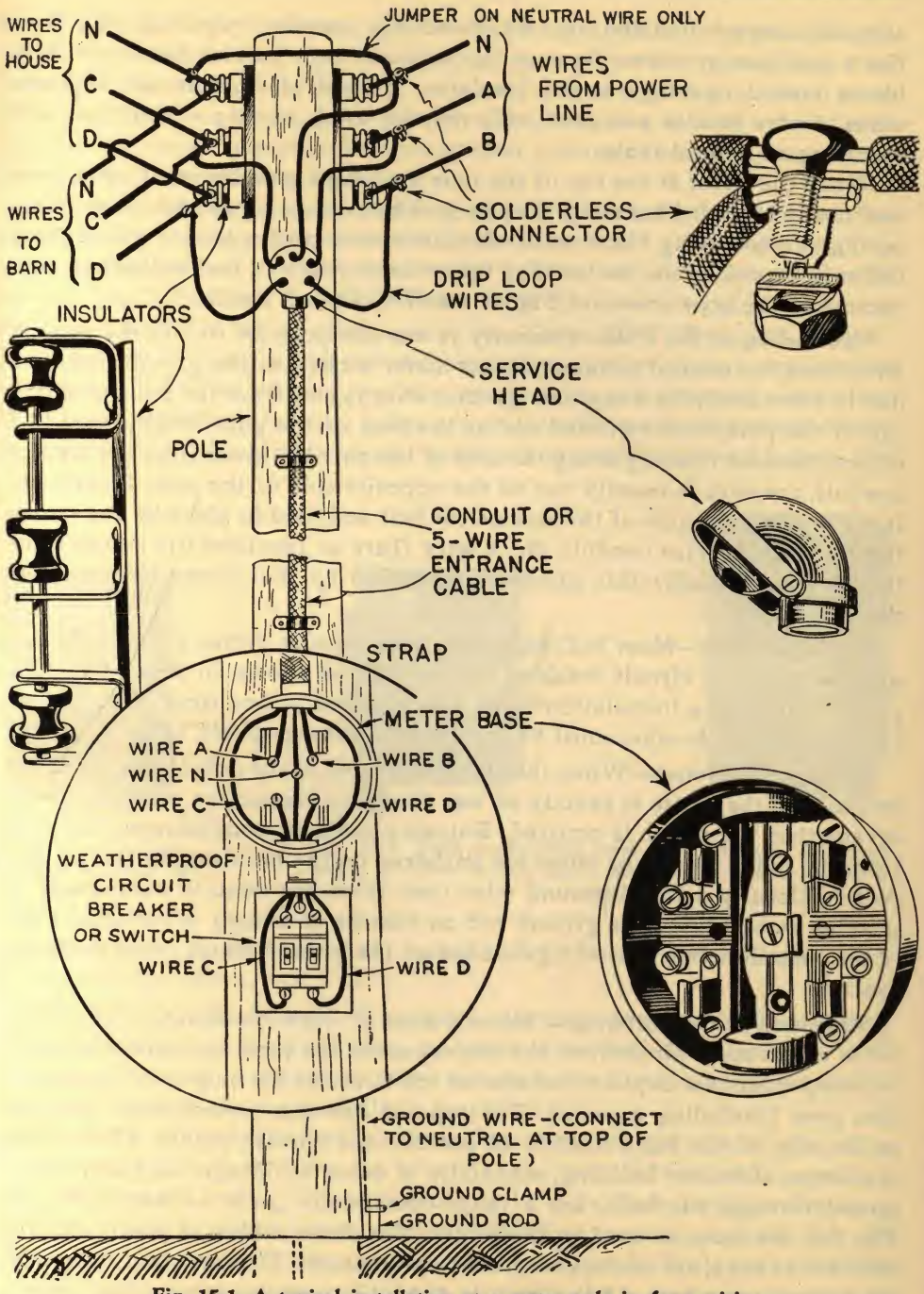


Fig. 15-1. A typical installation at a meter pole in farm wiring.

even 200-ampere installations are becoming common, requiring No. 4 or No. 2 and heavier wires. Be sure the entrance cap (service head) you buy has at least 5 openings in the insulator. Instead of conduit and separate wires, 5-wire service entrance cable may be used, costing a little less and requiring no special tools.

Since the wires at the top of the pole are of the weatherproof type, they will not be stranded but solid. At best it is hard to do a good job of splicing, taping and soldering No. 6 solid wires, but on top of a ladder it is doubly difficult, especially in winter. For that reason you will find solderless connectors of the type shown in Fig. 4-18 and 4-22 much handier.

Grounding at the Pole—Formerly it was the practice to run the ground wire from the neutral terminal in the meter socket, to the ground rod. Today in most localities a separate ground wire is run from the neutral at the top of the pole, to the ground rod at the base of the pole. While Fig. 15-1 shows this wire running along the side of the pole 90° away from the service conduit, the wire is usually run on the opposite side of the pole. Sometimes it is run along the side of the service conduit and held in place by the straps that hold the service conduit. No. 6 wire (bare or insulated) is suitable for the purpose. Usually this ground is installed by the Power Company or the R.E.A.

Switch at Pole—Most R.E.A. installations require either a fused disconnect-switch, or a circuit breaker, on the pole, as shown in Fig. 15-1. This permits the entire installation to be disconnected at one time. The cabinet of the switch or breaker must be the outdoor, weatherproof type.

Entrance at House—When the meter is located at the pole in the yard, the entrance to the house is exactly as was shown in connection with Fig. 6-16, except that the meter is omitted. Entrance cable or conduit runs directly from the point where the wires are anchored on the building, to the service switch. Usually a No. 6 ground wire (run from the neutral wire where it attaches to building, to a ground rod on outside of house) is installed even if the installation is already grounded at the pole. Consult your local inspector.

Entrance at Outbuildings—When a barn or other building is served by wires which come direct from the meter pole in the yard, the entrance at the building must be a duplicate of that of the house so far as general construction goes (including ground). The type of entrance switch used depends on the size of the barn, number of outlets, and similar points. If the barn is a large, elaborate building, especially if other buildings are going to be served through the barn, use a range-combination such as was shown in Fig. 6-3, the same as used in the house. The fuses which in the house are used for a range, are in the barn used to protect any 230-volt circuit serving, for example, a motor. If the barn is a smaller structure requiring only a

single circuit, the installation will no doubt be a 2-wire job and a simple switch, for example, that shown in Fig. 15-3 (except with only one fuse) may be used. In between, there are any number of stages so that the switch used may be either 2- or 3-wire, with provision for from two to half a dozen circuits. In any event, remember that the greater number of circuits you use, the less likelihood of blowing fuses later.

When the wires run to a building directly from the meter pole, the switch at the building must be one suitable for use as a service switch. The Underwriters' label in the switch may be one of two kinds: "Service Switch," or "Enclosed Switch." Those with "Service Switch" labels are always suitable for use as service switches. Those with "Enclosed Switch" labels are more common for controlling motors, water heaters and similar equipment, but *some* of them are also suitable for use as service switches. Which ones of a manufacturer's line are so suitable can be determined only by reference to the Underwriters' book of approved devices, unless the

Fig. 15-2. Typical weatherproof switch, mounted exposed to the weather.

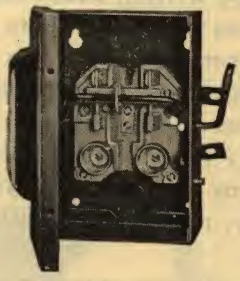


Fig. 15-3. Each outbuilding must have either a disconnect switch as shown at left above, or a circuit-breaker shown at right.

manufacturer tags the ones which are suitable as service switches also, with a notice to that effect.

Wires Between Buildings—First make sure that the wires used are strong enough for the length of the span, as outlined on page 26. Also make sure that the wires are big enough to carry the amperage involved without an unreasonable voltage drop, as outlined on page 25.

The wires are brought into miscellaneous outbuildings such as granaries, hog houses, hen houses, and so on by any of the methods outlined in connection with garage wiring, Figs. 12-12 to 12-14. The Code requires that any building which is served through another building must be so wired that the entire building can be disconnected by a single switch. If all the outlets in a building are light outlets and all are controlled by a single toggle switch,

that is sufficient. If there is in addition a plug-in outlet which is always live (or if there are two or more lights controlled by two or more separate switches), then another switch must be installed ahead of everything else so that the entire installation can be disconnected at one time. Usually a simple switch of the type shown in Fig. 15-3 is used. This costs only a couple of dollars. If it is a 2-wire installation, use a 2-pole switch with one fuse; if it is a 3-wire installation, use a 3-pole switch with two fuses. The neutral is never fused. The size fuse in this switch is determined by the size of the wires in the building. If only No. 14 wire is used, a fuse not larger than 15 amperes may be used; if No. 12 wire is used, a fuse not larger than 20 amperes may be used.

Instead of a fused switch, a circuit breaker may be used, also shown in Fig. 15-3. Such a breaker now costs very little more than a switch. If it trips, it can be restored by merely re-setting it, with nothing to replace. The mechanism inside this device is the same as that described in connection with service entrance equipment, Fig. 6-4.

Barn and Outbuilding Wiring—Armored cable and conduit should not be used. A long chapter could be written about the reasons, but basically they can be summed up as follows: in barns there is a combination of almost continuous moisture, plus chemicals from the urine of animals. The combination leads to quick rusting out of sections of the conduit or armor. Moreover, the best ground on a farm is a poor ground as compared with a continuous underground city water system. All this means that while conduit or armored cable systems are excellent systems in cities, they quickly become dangerous on farms; many electrocutions of farm animals can be traced to such installations.

Therefore, on farms, use only non-metallic sheathed cable. Then remember that in the winter moisture collects very freely on the cold outside walls of buildings, and that moisture is an enemy of all electrical insulations. Therefore avoid so far as is possible, attaching cable, boxes or other electrical components on the outside walls of barns and similar buildings.

Be especially careful of your selection of the type of non-metallic sheathed cable, for outbuilding use. The ordinary cable shown in Fig. 6-8 has been used for this purpose for many years, but these years of experience have shown that the outer braid tends to rot out, especially in colder climates where there is much condensation of moisture in the winter. Recently a special kind of this non-metallic sheathed cable has become available, especially designed for farm use.

In place of the usual outer braid of fabric, this special farm cable has an outer jacket of plastic or neoprene which will withstand the severe conditions of farm outbuildings. It costs more but will far outlast the ordinary cable. If for any reason you cannot obtain this special cable, use the ordi-

nary, but paint it with a good asphalt paint wherever it runs through a bored hole in a timber, or where it is attached held by means of a strap.

As to the type of boxes, follow local practice. If metal, use the galvanized, not the black. More and more the use of boxes made of bakelite or porcelain is growing. Instead, special devices (combining outlet box and cover and device such as switch or receptacle, already described in Chapter 8) are often used. *Do not use brass shell sockets; use only those made of an insulating material.*

Location of Outlets—Be liberal in the installation of light outlets. The ideal is one in the aisle behind every stall. A minimum is one behind every two stalls. Do not install these lights on the bottom of the joists, for they are too easily damaged. Put them up between the joists with the bottom of the bulb approximately flush with the bottom of joists. Lights should be controlled by toggle switches, and at least one of them should be controlled by a pair of 3-way switches, so that it can be turned on from either entrance to the barn. This will be found a great convenience.

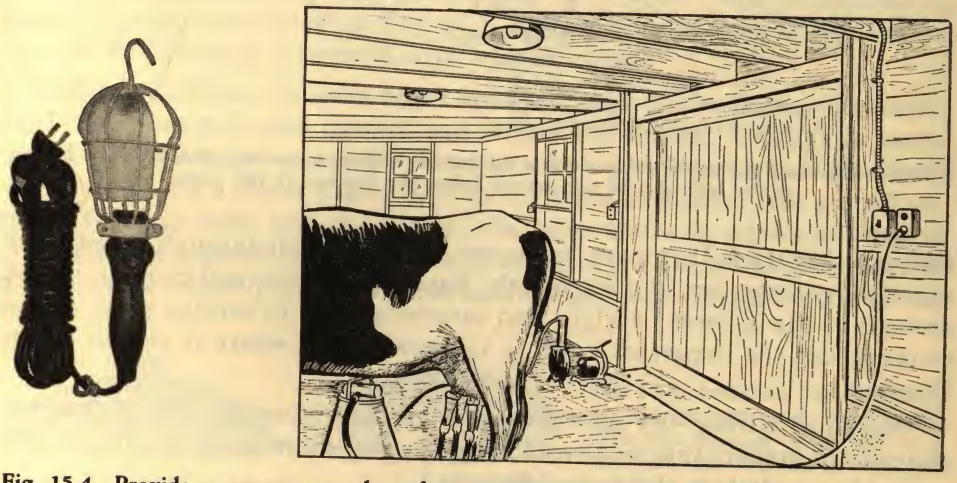


Fig. 15-4. Provide a generous number of receptacle outlets in the barn. They are useful for a trouble-light shown at left, a milking machine shown at right, and for many other purposes.

Switches should be located in protected spots so that they cannot be damaged by animals rubbing against them. Mount them at elbow height, so that they can be operated even if both your hands are full.

Do not overlook a number of receptacle outlets in the barn. They will be very handy for the operation of a trouble-light extension cord shown in Fig. 15-4, milking machine motors, clipping machine motor, and many other applications.

At this point, review Chapter 8 covering the use of non-metallic cable in general. The wiring of barns and other buildings is the same as there outlined for other buildings, with some points to watch specially.

It is best not to run cable along the bottoms of joists or other similar timbers, because it would be more or less subject to injury. Don't run it at right angles across the bottoms of the joists even if running boards are used. The cable will receive far more protection against mechanical injury if run along the side of a beam, then out along the side of a joist into the middle of the aisle or driveway at each point where a light is to be installed, as

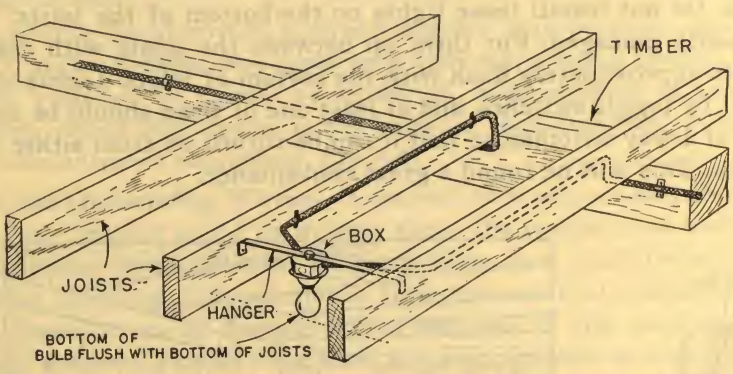


Fig. 15-5. It is best to run the cable along a substantial timber, to prevent damage. The bottom of the bulb should not extend below the bottom of the joists.

shown in Fig. 15-5. If it must run across timbers, run it through bored holes or, as a last resort, on running boards. Each installation will be different on account of the different designs and carpentry used in various parts of the country, and the important point is to install cable where it cannot be injured.

Hay-Mow Wiring—Be sure that one of the lights actually lights the stairway or ladder; this will avoid accident. Hay-mow lights should be controlled by a switch on the ground floor.

The dust in a hay-mow is explosive, and an explosion can occur if an exposed bulb is broken. When a bulb breaks it burns out, but during that short fraction of a second while it is burning out, the filament is at an exceedingly high temperature, and can set off an explosion. Therefore for hay-mows, it is best to use dust-tight enclosures for bulbs, known as vapor-proof receptacles, as shown in Fig. 15-6. In many localities their use is required.

The Code requires that non-metallic cable must be given special protection when it runs through a floor. For hay-mow wiring, most inspectors will require more protection than the Code calls for. In a hay-mow, there is

always danger that a pitchfork will puncture unprotected cable and cause a short-circuit. Therefore it is quite reasonable that inspectors require extra protection, from the floor up to a point where hay will never be in contact with the cable. Occasionally an inspector will permit cable installed in the

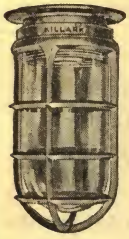


Fig. 15-6. For safety's sake, use vapor-proof receptacles in hay-mow wiring.

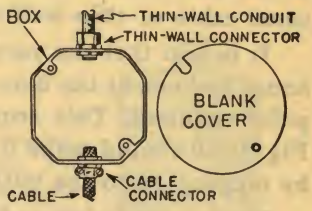


Fig. 15-7. Method of changing over from cable wiring to conduit wiring.

corner formed by wall and stud, with a piece of board nailed over it for protection. Sometimes the cable is run through pipe. A sensible installation is made by using conduit, either rigid or thin-wall, from a point on the first floor to a point above the hay. The change-over from cable to conduit is made very simply as shown in Fig. 15-7. Rubber-covered wire is used inside the conduit. The box is covered with a blank cover.

Reflectors—When exposed bulbs are used, half of the light goes downward, the other half goes upward and strikes the ceiling. Ceilings in barns and similar buildings are usually dirty, so that most of the light is absorbed, not reflected. As a result nearly half of the light is wasted. Use a good reflector for each bulb, and the half of the light which is otherwise wasted will strike the reflector and be thrown downward. *A 60-watt bulb with a good clean reflector usually gives as much useful light as a 100-watt without the*

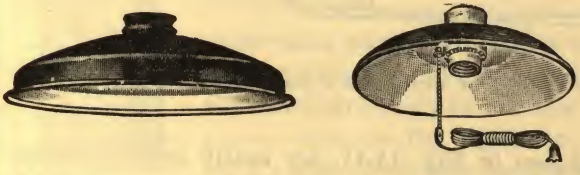


Fig. 15-8. Reflectors pay dividends. A 60-watt bulb with a reflector gives you as much useful light as a 100-watt bulb without a reflector. Keep the reflectors clean.

reflector. Reflectors are inexpensive and some available types are shown in Fig. 15-8. A kerosene lantern with a smoky chimney gives little light; clean the reflectors regularly for maximum efficiency.

Yard Lights—Every farm will have at least one, and usually two, yard lights of the general type shown in Fig. 15-9. These are inexpensive, and not only enable you to work in the yard without having to carry a lantern or flashlight, but are extremely useful in preventing accidents. A flip of the switch lights up the entire yard.

With some brands of yard lights, it is hard to make an installation in strict accordance with Code requirements. It is best to use the type shown in Fig. 15-9, which has a cast-iron outlet-box-type of flange for pole mounting. Weatherproof cable or conduit is attached to an opening in the bottom of the cast box, which is tapped to fit either ½ inch rigid conduit or the usual cable or thin-wall conduit connector.

It is best that the yard light be controlled by 3-way switches, one at the house and one at the barn. A 4-way switch can be installed at any additional point required. This requires a maximum of three wires. The diagram in Fig. 15-10 should make it clear. It is contrary to Code to feed the yard light by tapping on to the wires at the meter pole.

Outdoor Switches and Receptacles—Inexpensive weatherproof cast hous-

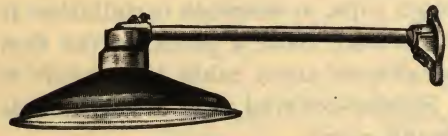
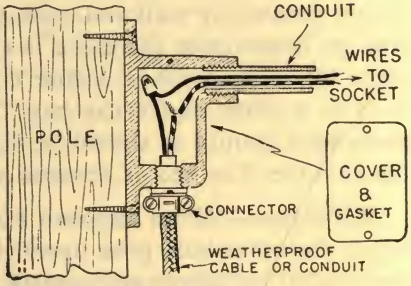


Fig. 15-9. A typical yard-light. Note the construction at the right, making a thoroughly weatherproof installation.



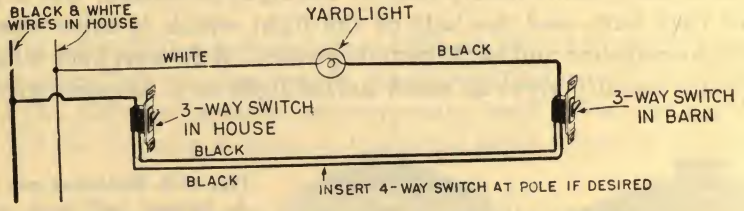


Fig. 15-10. Proper method of wiring for a yard light.

ings for toggle switches, as shown in Fig. 15-11, are easily available. Any type of toggle switch (single-pole, 3-way or 4-way) may be mounted inside of it, and it will then be operated by the external handle. This makes a thoroughly weatherproof installation.

Outdoor receptacles are also available and one is shown in Fig. 15-12. This receptacle is rated at 15 amperes which is sufficient for most jobs. If a large motor is to be used in portable fashion, a much heavier weatherproof receptacle is required. Such a receptacle costs upward of ten dollars; however, an electric range receptacle such as is shown in Fig. 12-18, rated at 50 amperes at 250 volts, may be used. While this receptacle is acceptable for

indoor use only, there is no reason why you cannot build a thoroughly weatherproof housing around it so that even if mounted outdoors, the conditions are the same as indoors. Another alternative is to mount the outlet inside of a building, with a small door nearby which ordinarily would be closed. When the portable motor is to be used, open this door and run the motor cord through it to the outlet inside.

Fig. 15-11. A weatherproof housing for a toggle switch. An ordinary switch is used inside of it.

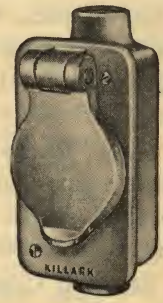


Fig. 15-12. A weatherproof receptacle. The cover closes automatically when the receptacle is not in use.

Poultry Houses—It has been well established that if light is provided to lengthen the day in poultry houses, egg production will greatly increase. For this purpose, one 40- or 50-watt bulb with a reflector about six feet from the floor, for every 200 square feet of floor area, is considered sufficient.

Fig. 15-13. A time - switch for poultry house.

When the time comes to turn the lights off, don't turn all of them off at the same time. The lights should first be dimmed and after half an hour or so turned off completely. Unless this is done, the hens will not go to roost but will stay where they are when the light is turned off. In the morning, the procedure should be reversed, dim light first, then a brighter light.

All this, of course, can be done by hand by the use of the proper switches, but it is much simpler to install a special time switch designed for the purpose. At the time set, this clock turns on the lights in the evening, later dims them, then turns them off; in the morning, the procedure is reversed. An inexpensive time switch of this type is shown in Fig. 15-13.

CHAPTER 16

Electric Motors

A working man can deliver no more than 1/10th to 1/8th horsepower continuously over a period of several hours. If the man is paid 75c an hour, it costs at least $6.00 for a horsepower for an hour. At average rates an electric motor will deliver a horsepower for an hour for 5c. The motor costs little to begin with. It will operate equally well on a hot day or a cold day. It never gets tired, and costs nothing except while running. It uses electricity only in proportion to the power it is called upon to deliver. With reasonable care, it will last for many years.

How Motors Are Rated—A motor is rated in horsepower. This means that (except for special-purpose motors) it will deliver the horsepower stamped on its nameplate hour after hour, all day and all week without a stop, if necessary.

Starting Capacity—Motors deliver far more power while starting, than after they are up to full speed. The proportion varies with the type of motor; some types have starting torques 4 or 5 times greater than at full speed. Naturally the watts consumed during the starting period are much higher than while running at full speed. That means the motor will heat up quickly if the motor does not reach full speed, because of too heavy starting load. Therefore the right kind of motor must be used for each machine, depending on how hard it starts. This will be explained later in this chapter.

Overload Capacity—Almost any good motor will for short periods develop from 1½ to 2 times its normal horsepower, without harm. Thus a 1 hp. motor is usually able to deliver 1½ hp. for perhaps a quarter of an hour, 2 hp. for a minute, and usually even 3 hp. for a few seconds, without harm. Of course, no motor should be deliberately overloaded continuously, but this ability of a motor to deliver more than its rated horsepower is most convenient. For example, in sawing lumber, ½ hp. may be just right, but when a tough knot is fed to the saw blade, the motor will instantly deliver, if needed, 1½ hp., dropping back to its normal ½ hp. after the knot has been sawed. A water pressure system using a ½ hp. motor may ordinarily require only ½ hp. or less, except for the last few minutes of running while the pressure builds up from 35 to 40 pounds, when ¾ hp. may be needed. The motor will automatically take care of it.

Gasoline Engines vs. Electric Motors—A gasoline engine is rated at the maximum power it can deliver *continuously*. Thus, an engine rated at 5 hp. can deliver 5 hp. continuously, but unlike an electric motor, it cannot, even for a short time, deliver more than 5 hp. This explains why it is often possible to replace an engine of 5 hp. with an electric motor sometimes as small

as 2 hp. If the engine being replaced always runs smoothly, with little effort, if it seldom labors and slows down, it can be replaced with an electric motor of much smaller horsepower. If, on the other hand, the engine is always laboring at its maximum output, then the motor that replaces it should be of the same horsepower as the engine, because no motor should be expected to *continuously* deliver more than its rated horsepower.

Power Consumed by a Motor—The watts drawn from the power line by a motor are in proportion to the horsepower it is delivering. The figures for a 1 hp. motor are as follows:

While starting,	a 1 hp. motor draws about	4,000 watts.
While idling,	a 1 hp. motor draws about	200 watts.
While delivering ¼ hp.	a 1 hp. motor draws about	400 watts.
While delivering ½ hp.	a 1 hp. motor draws about	600 watts.
While delivering ¾ hp.	a 1 hp. motor draws about	800 watts.
While delivering 1 hp.	a 1 hp. motor draws about	1,000 watts.
While delivering 1½ hp.	a 1 hp. motor draws about	1,500 watts.
While delivering 2 hp.	a 1 hp. motor draws about	2,000 watts.
While delivering 2½ hp.	a 1 hp. motor draws about	2,600 watts.
While delivering 3 hp.	a 1 hp. motor draws about	3,300 watts.

Motors are designed to operate at greatest efficiency when delivering their rated horsepower; while delivering more or less power, the efficiency usually falls off. In other words, it costs a little more per hour to run a 1 hp. motor at half load, than it does to run a ½ hp. motor at full load. The 1 hp. motor, while delivering only ½ hp., as per table above, consumes about 600 watts; a ½ hp. motor delivering ½ hp., consumes about 525 watts. In the long run therefore, especially if the motor must run many hours, it will be less costly to have a small motor for a small load, than to run a small load with a big motor that you may happen to have handy.

Speed of Electric Motors—The most common speed for an electric motor is 1800 rpm. while idling, which drops down to somewhere between 1725 and 1750 rpm. while delivering rated horsepower (the horsepower stamped on the nameplate). When overloaded the speed drops further. If the overload is increased too far, the motor finally stalls. Low voltage also cuts the speed.

Motors of other speeds are built, such as 900, 1200, and 3600 rpm. These cost more; in case of motor failure, they are hard to replace quickly because they are seldom stocked, which makes it necessary to change pulleys and belts, and leads to similar inconveniences. Use an 1800 rpm. motor wherever it is at all possible. If a very slow speed is needed, use a motor which runs at 1800 rpm. but has built-in gears which cut the speed of the drive shaft to a much lower figure.

The speed of ordinary A.C. motors *can not be controlled* by rheostats, switches or similar devices. Special variable speed motors are obtainable but

they are very expensive special-purpose motors and will not be covered here.

Temperature Rise in Motors—All electrical devices heat up in use; motors are no exception. However, if a well designed motor is run continuously, delivering its full rated horsepower (the horsepower stamped on the nameplate), the temperature of the motor will not increase by more than 40° Centigrade or *72° Fahrenheit, *over and above room temperature.* On a hot summer's day the temperature of the air in an enclosed pump-house, for example, may be as high as 110°; add to this the 72° rise and you have a total of 182°, not far below the boiling point of water. This will feel decidedly hot to the hand but will be entirely safe so far as the motor is concerned. Install motors so that air can get at them for cooling.

Motor Protection—It takes a good deal more power to start any machine than it does to keep the same machine running; this is proved by the fact that you start your automobile in low gear. So also with electric motors—it takes considerably more amperes to start a motor, than to keep it running at full speed at rated horsepower. An ordinary washing-machine motor may require from 5 to 6 amperes while delivering full rated horsepower, but may require as much as 30 amperes for a few seconds while coming up to speed.

Likewise, when a motor is overloaded so that it is forced to deliver more than its rated horsepower, it consumes more than its normal amperage from the line, as the table on page 119 shows.

A motor will not be damaged by current considerably greater than normal flowing through it *for a short time;* it will burn out if excessive current flows *for a considerable time* (just as a man can walk at say 4 miles per hour for a long distance, but can't run at 10 miles an hour for more than a short distance). Therefore it is necessary to protect the motor with a device which will let a current considerably more than normal flow for a *short* time, but will disconnect the motor if it flows for a *considerable* time. Unless this is done, the motor may burn out, requiring an expensive rewinding job.

The simplest protective device is an ordinary fuse, but this hardly protects the motor at all; if it is big enough to carry the *starting* amperage, it is so large that it will carry the overload amperage continuously, thus not protecting against overloads.

Fuses of the time-lag type described on page 35 are very suitable; the amperage of the fuse should not be over 140% of the amperage stamped on the nameplate of the motor. If an amperage greater than this is selected, it will provide less protection against overloads. When using fuses to protect motors, use one in each wire if the motor operates on 230 volts, but only one (in the black ungrounded wire) if it operates on 115 volts.

The best protection for a motor is a thermal overload device which car-

* Do not confuse *change* in readings of thermometers with their *actual* readings. When a Centigrade thermometer reads 40°, a Fahrenheit thermometer reads 104°. While a Centigrade thermometer changes by 40°, the Fahrenheit changes by 72°. Thus, if the Centigrade changes from 40° to 80°, the Fahrenheit changes from 104° to 176° (by 72°).

ries normal current permanently without tripping, carries a small overload for a long time, and trips quickly if a very large overload is imposed. In the case of small motors such devices are often built into the motor, and are known by various names such as "Thermotron," "Thermoguard," and so on. When they trip, merely reset them after the motor cools off. Thermal overload devices are also available in the form of separate devices which usually include start and stop switches; a typical one is shown in Fig. 16-1.

Fig. 16-1. Motor overload switch.

Types of Motors—There are many different types of motors in use. Only the more common ones can be described here. The current found in practically all homes and farms is A.C. (alternating current) 115 or 230 volts, usually 60 cycles, in a few localities 25 or 50 cycles. With rare exceptions, it is what is known as *single*-phase A.C.; the incoming wires may be either two or three in number. Three-phase A.C. is common in factories but seldom found in homes or farms; there may be either three or four incoming wires.

Split-Phase Motors—This type of motor operates only on single-phase A.C. It is the most simple type of motor made, which makes it relatively trouble-free; there are no brushes, no commutator. It is available only in sizes of ⅓ hp. and smaller. It draws a very heavy amperage while starting. Once up to full speed, this type of motor develops just as much power as any other type of motor, but it is not able to start heavy loads. Therefore it should never be used on any machine which is hard to start, such as a deep-well water pump, or an air compressor that has to start against compression. It may be used on any machine which is easy to start, or on one where the load is thrown on after the machine is up to full speed. It is entirely suitable for washing machines, grinders, saws and lathes, and general utility use. It may be used on paint sprayers which do not start against compression, but not on those that start against pressure.

Capacitor Motors—This type of motor also operates only on single-phase A.C. It is a comparatively new type of motor, having come into general use during the last 20 years. In construction it is almost identical with the split-phase type, with the addition of a "capacitor" or a "condenser" which enables it to start much harder loads. There are several grades of capacitor type motors available, ranging from the home-workshop type which start loads from 1½ to 2 times as heavy as the split-phase, to the heavy-duty type which will start almost any type of load whatever. Capacitor motors usually are also more efficient than split-phase, using less watts per horsepower. The amperage consumed *while starting* is about half that of the split-phase type. Capacitor motors are made in any size but are commonly used only in sizes up to 3 hp.

Repulsion-Induction Motors—This motor, commonly called an "R-I" motor, also operates only on single-phase A.C. Usually it is so designed that it will operate on either 115 or 230 volts, by interchanging four wires which come out of the motor. It has a very large starting ability and should be used for the heavier jobs; it will "break loose" almost any kind of hard-starting machine. The starting current is the lowest of all the single-phase types of motors.

Three-Phase Motors—These motors, as the name implies, operate only on three-phase A.C. Three-phase motors in sizes ½ hp. and larger, cost less than any other type, so by all means use them if you have 3-phase current available. *Do not assume because you have a 3-wire service, that you have 3-phase current; more likely you have 3-wire 115/230 volt single-phase current. If in doubt, see your power company.*

Direct Current Motors—Direct current (D.C.) is found in the downtown sections of some large cities like Chicago and New York, and in some small towns. All 32-volt farm plants are direct current as are a few of the 110-volt farm plants.

Motors for direct current are of one type only and have no special name or type. They are suitable for any general purpose work. The speed is usually around 1800 but the speed varies considerably more than in A.C. motors, and varies considerably with the voltage. Idling it may be as high as 2400 rpm., unlike the A.C. type which never exceeds 1800 rpm. for common types.

Universal Motors—This type of motor operates on either D.C. or single-phase A.C. of 60 or any other cycles. However, it does not run at a constant speed, but varies over an extremely wide range. Idling, a universal motor may run as fast as 15,000 rpm., while under a heavy load the same motor may slow down to 500 rpm. This of course makes the motor totally unsuitable for general purpose work. It is used only when built into a piece of machinery where the load is constant and definitely predetermined. For example, you will find this motor on your vacuum cleaner, your sewing machine, on some types of fans, on electric drills, etc.

Reversing Motors—The direction of rotation of a repulsion-induction motor can be changed only by shifting the position of the brushes. On other types of A.C. motors it is changed by reversing two of the wires coming from the inside of the motor. If a motor must be reversed often, a special switch may be installed for the purpose.

Problems with Large Motors—Often a farmer feels the need for a motor of 10 hp. or larger. Upon looking into the subject, he learns that *single*-phase motors larger than 5 hp. are almost impossible to find and are very expensive.

He also discovers that the transformer serving his farm is too small to operate a motor larger than 3 hp. or possibly 5 hp. The power company probably objects to putting in a larger transformer because that would be just like using a 10-ton truck all year round, just because 10 tons had to be hauled once in a while, but the usual load only a ton or two.

In turning to 3-phase motors, he learns that they are available in any size, cost less per horsepower than single-phase motors, but discovers that the nearest 3-phase line is many miles away.

What then is he to do? The answer is to use smaller machines. For example, instead of a large hammer-mill which requires 10 hp. or 15 hp. to operate, use a smaller mill which requires only 3 or 5 hp. Small hammer-mills are now available which are very efficient, having more capacity *per horsepower* than the larger mills. Even ear corn can be ground with as little as 2 hp. The smaller machine may have to be operated more hours altogether, but may require fewer men to operate, costs less to begin with, and costs less to operate because the smaller machine has more capacity per horsepower.

Care of Motors—Motors require very little care. The most important is proper oiling of the bearings. Use a very light machine oil, such as S.A.E. No. 10, and use it sparingly—most motors are oiled too much. Never oil any part of the motor except the bearings; under no circumstances put oil on the brushes, if your motor has brushes.

If your motor has a commutator and brushes, occasionally while the motor is running, hold a very fine piece of sandpaper (never emery) against the commutator to remove the carbon that has worn off the brushes. *Be sure you are standing on something absolutely dry to avoid shock.*

Bearings—In most commonly used motors, there is a choice of sleeve bearings or ball bearings. If the motor is to be operated with the shaft in the ordinary horizontal position, there is no need for ball bearings. If the motor is to be operated with the shaft in an up-and-down position, ball bearings should be used because the usual sleeve-bearing construction lets the oil run out. Ball bearings are also better able than sleeve bearings to absorb the weight of the rotor. Ball bearings of some types are filled with grease and permanently sealed, thus doing away with the nuisance of greasing. If this type is purchased, be sure the bearings are double-sealed, that is, with a seal on each side of the balls. Some bearings are sealed on only one side so that the grease can still get out on the other side.

Belts and Pulleys—Keep belts reasonably loose; most belts are run too tight. Tight belts cause worn belts, worn bearings, and burned-out motors; they increase the amount of power required to operate a machine. "V" belts in general are most suitable; for motors bigger than ½ hp. two or more

belts in parallel are required. "V" belts may be operated quite loosely with considerable slack.

Regardless of the type belt used, don't use very small pulleys. The smaller the pulley, the sharper the bend in the belt, and the shorter its life. Moreover, a belt running over a 1½-inch pulley makes contact with only a very small surface of the pulley (measured in square inches). This leads to considerable slipping and extra belt wear. For any speed, there is a choice of several pulley combinations; for example, a 1½-inch pulley on motor and 3-inch pulley on machine, or a 3-inch pulley on motor and 6-inch pulley on machine, give the same machine speed. Use the larger pulleys for longest belt life and greatest efficiency.

The following table will be helpful in determining pulley combinations for any speed wanted on the machine. It is figured for a motor running at about 1750 rpm. and some allowance has been made for belt slippage.

Diam. Motor Pulley	Diameter of Pulley on Machine, Inches														
	1¼	1½	1¾	2	2¼	2½	3	4	5	6½	8	10	12	15	18
1¼	1725	1435	1230	1075	950	850	715	540	430	330	265	215	175	140	115
1½	2075	1725	1475	1290	1140	1030	850	645	515	395	320	265	215	170	140
1¾	2400	2000	1725	1500	1340	1200	1000	750	600	460	375	315	250	200	165
2	2775	2290	1970	1725	1530	1375	1145	850	685	530	430	345	285	230	190
2¼	3100	2580	2200	1930	1725	1550	1290	965	775	595	485	385	325	255	215
2½	3450	2870	2460	2150	1900	1725	1435	1075	850	660	540	430	355	285	240
3	4140	3450	2950	2580	2290	2070	1725	1290	1070	800	615	515	430	345	285
4	5500	4575	3950	3450	3060	2775	2295	1725	1375	1060	860	700	575	460	375
5	6850	5750	4920	4300	3825	3450	2865	2150	1725	1325	1075	860	715	575	475
6½	8950	7475	6400	5600	4975	4480	3730	2790	2240	1725	1400	1120	930	745	620
8	.....	9200	7870	6900	6125	5520	4600	3450	2750	2120	1725	1375	1140	915	765
10	.....	.....	9850	8620	7670	6900	5750	4300	3450	2650	2150	1725	1430	1140	950
12	.....	.....	.....	.....	9200	8280	6900	5160	4130	3180	2580	2075	1725	1375	1140
15	.....	.....	.....	.....	.....	.....	8635	6470	5170	3970	3230	2580	2150	1725	1425
18	.....	.....	.....	.....	.....	.....	.....	7750	6200	4770	3880	3100	2580	2070	1725

Wiring for Motors—Wiring for motors is not different from wiring for other devices except that the size of wire used must be watched very carefully, and that switches for starting and stopping the motors are usually installed near the motor. If the right size wire is not used, there may be so much voltage drop in the wires that you may have only 90 volts on the motor instead of 115, which in turn means that the motor will overheat, and develop only 70% of the power it would deliver at normal voltage. If the motor is on a water pump or other hard starting device, the motor may not

be able to start on the low voltage with the result that it will burn out. The table below will show the size of wire to use when the motor is various distances from the fuse cabinet.

Horsepower and Voltage of Motor		One-Way Distance to Motor							
		100′	150′	200′	250′	300′	400′	500′	1000′
¼ hp.	115-Volt	14	14	14	12	12	10	10	8
⅓ hp.		14	14	12	12	10	10	8	6
½ hp.		12	12	10	10	10	8	8	4
¾ hp.		12	12	10	10	8	8	6	4
1 hp.		10	10	8	8	8	6	6	2
1½ hp.		10	8	8	8	6	6	4	2
2 hp.		10	8	8	6	6	4	2	0
¼ hp.	230-Volt	14	14	14	14	14	14	14	14
⅓ hp.		14	14	14	14	14	14	14	12
½ hp.		14	14	14	14	14	14	12	10
¾ hp.		14	14	14	14	14	12	12	10
1 hp.		14	14	14	14	12	12	10	8
1½ hp.		14	14	14	12	12	10	10	8
2 hp.		14	14	12	12	10	10	8	6
3 hp.		12	12	10	10	10	8	8	4
5 hp.		8	8	8	8	6	6	6	2

For 32-volt motors, see page 126.

The sizes given in the table above are correct only if the motor is not overloaded. Most motors will stand 200% overload and there are many cases when a ¼ hp. motor is made to develop ½ hp., at least while starting. To be on the safe side therefore, it is best to use wire at least one size larger than recommended. If you must use an extension cord on a motor, remember that ordinary extension cord is only No. 18 wire. Make a special cord out of No. 14 wire.

CHAPTER 17

Wiring for Home Light Plants

Most home light plants sold today are of the 115-volt (or 115-230-volt) 60-cycle A.C. type, producing exactly the same type of power found in city homes or in farm high-lines. The wiring for such a plant should therefore be done in the same way as if power-company electricity were to be used. True, the main switch may be omitted for the plant may be stopped while working on the wiring. However, the wiring should still be broken down into circuits which later will be connected to a main-switch-and-fuse-cabinet combination, if commercial power becomes available. Be sure each circuit is properly fused.

Proceeding in this fashion will save much money later, when power-company power becomes available. (When that happens don't sell the power plant: save it, install it as an emergency source of power during periods of power failure. This is especially important on farms for if R.E.A. power fails for 24 hours, the emergency plant will keep oil burners in operation, prevent a batch of eggs in the incubator from spoiling, run the milking machine. A simple double-throw switch will connect the load to either the R.E.A. power or the emergency plant, as needed.)

32-Volt Light Plants—Proceed as described in previous chapters, but use heavier wire. No. 12 is the lightest permitted by Code, but for convenience outlets, motors and other heavy loads, use only No. 10 or heavier.

Amperes	Watts at 32 v.	TABLE OF WIRE SIZES FOR 32-VOLTS						
		No. 12	No. 10	No. 8	No. 6	No. 4	No. 2	No. 0
3	96	175	275	450	700	1,000	1,750	2,750
5	160	100	160	250	425	650	1,000	1,600
7½	240	65	110	170	275	425	700	1,200
10	320	50	80	125	210	325	500	800
15	480	35	55	85	140	225	350	600
20	640	25	40	60	105	160	250	400
25	800	*20*	30	55	85	130	210	325
30	960	*15*	25	45	70	110	175	300
35	1,120		*20*	40	60	100	150	250
40	1,280			30	50	80	125	200

In table above, figures represent ONE WAY distances, not the total length of wire back and forth.
Distances shown in *italics* indicate that for the amperages in the same line in column at left, only weatherproof wire may be used. For all other distances either rubber-covered or weatherproof wire may be used.
Each figure indicates the maximum distance each size wire will carry the different amperages in the left column, with 5% voltage drop, the customary figure in 32-volt work. If you wish to limit the voltage drop to 2½% cut all distances in half.
This table may also be used for 32-volt motors. A ¼ hp. motor uses about 7½ amperes, a 1/3 hp. about 10 amperes, and a ½ hp. about 15 amperes.

6-Volt Light Plants—Plants of this type are entirely practical if the owner understands the limits of what they are able to do. Such a plant should not be expected to do more than operate a radio and a few small lights a few hours each day. A good test is to charge the 6-volt battery of such a plant completely, then use it without running the generator at all. It the battery is run down in less than a week, the plant is too small.

It is not practical to run wires more than 50 feet from a 6-volt plant unless very large wires are used, in which case it would be more sensible to use a 12-volt or 32-volt plant with smaller wires. Usually pull-chains are used instead of switches because switches require a few extra feet of wire, which cause additional voltage drop. The following table will show how many feet (one-way distance) each size wire will carry various wattages at 6 volts with ½ volt or about 8% voltage drop:

Watts at 6 v.	Approx. Amperes	TABLE OF WIRE SIZES FOR 6 VOLTS					
		No. 14	No. 12	No. 10	No. 8	No. 6	No. 4
15	2½	40	65	100	150	275	450
25	4¼	25	40	65	100	175	250
40	7	15	22	35	55	100	150
50	8		20	30	45	80	125
60	10		15	25	40	65	100
75	12½			20	30	50	80
90	15			17	25	45	70
120	20				20	35	50
150	25				15	25	40

12-Volt Light Plants—Use 6-volt table above (disregard "amperes" column), but multiply all distances *by four.*

Grounding—Wiring for home light plants is not required by Code to be grounded, unless the wires run between buildings, in which case one of the two wires should be grounded. It is very sensible practice, when wiring for a 32-volt system, to do everything required for 115/230-volt wiring (and in addition use the heavier wire sizes required for 32-volt work). Then if an REA line comes along later, no rewiring will be necessary.

Batteries—In this chapter, a word about the care of farm plant batteries should not be amiss. It is entirely safe to say that most batteries that have worn out would have lasted their owners twice as long as they did, had they received proper care.

Some owners think they are taking extra good care of their battery if they always keep it fully charged, charging it immediately when it is partly run down. The opposite is true—it ruins a battery quickly so that frequently its life is reduced to as little as 25% of normal. For maximum life, charge the battery fully, then use it till it is at least 85% discharged, then charge it all the way up, and repeat through complete cycles of charge and discharge; this will give maximum life.

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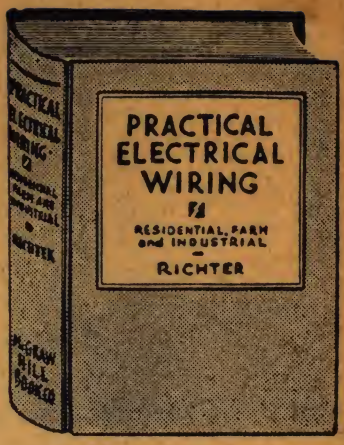

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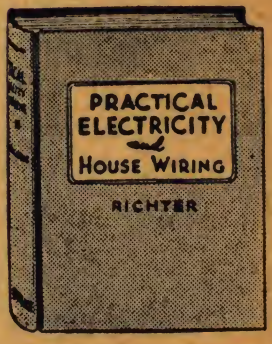

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